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THE INFLUENCE OF HOLE PROCESSING AND JOINT VARIABLES ON THE FRACTURE LIFE OF SHEAR JOINTS

Metals Behavior Branch
Metals and Ceramics Division

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Final Report for Period May 1975 to May 1977

AIR FORCE MATERIALS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
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FOR THE COMMANDER

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Four hundred eighty fatigue test specimens were cycled in constant amplitude fatigue, using four designs, zero, 5, 50, and 100% load transfer, with two fasteners installed, and processing conditions such as hole diameter and angle, surface roughness, fastener preload, faying surface fretting protection, and hole cold-work, individually varied. The data was collected in computer files, and multiple stepwise regression analysis performed with specimen life as the dependent variable. A family of 15 models for predicting variation in fatigue lives was developed. Factors most effective were determined.

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Hole surface roughness was found generally either not to enter into the predictive equations, or to enter very weakly into the model. When hole roughness entered the models, its effects were almost equally divided between increasing roughness showing increases or decreases in fatigue life.

Fastener interference was determined to be a key parameter in determining fatigue life. Interference was approximately twice as effective as hole cold-working in fatigue life enhancement.

FOREWORD

This report was prepared by Major Thomas K. Moore of the Structures Division, Directorate of Airframe Engineering, Aeronautical Systems Division, ASD/ENFSS; and later with the Airlift System Program Office, Aeronautical Systems Division, ASD/YASM. It was submitted by the author in May 1977 as a part of the cooperative inhouse research effort with the Air Force Materials Laboratory. The work was performed under Project 2418, "Metallic Structural Materials", Task 241803, "Metals Behavior", Inhouse Work Unit 24180301, "Environmental Effects".

The report covers work conducted from May 1975 to May 1977. The research was conducted under the technical direction of Dr. Charles T. Lynch (AFML/LLN), Metals Behavior Branch, Metals and Ceramics Division, Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio.

This research grew from experiences which this writer had as a Structural Materials Applications Engineer in the Aeronautical Systems Division, Wright-Patterson AFB, Ohio. While the analysis of a joint's static strength is relatively straightforward, the fatigue analysis is more complex. The usual practice for fatigue life has been to allow a "scatter factor", normally 4X, and to proceed on the basis of the analytical and test results. However, there are manufacturing quality conditions which seem to influence the fatigue life of a given joint, many of which are not adequately documented or understood. If these conditions could be defined and quantified, it would be possible not only to predict more accurately the fatigue life of critical joints, but to specify more rationally the desired production quality for critical joints, and to define the effect of an out-of-tolerance condition. Cost savings could be realized by avoiding the inspection of parameters which do not significantly influence joint fatigue life.

To an extent only hoped for at the onset, this study has been successful, and the conditions which influence fatigue life have been determined.

This research would not have been possible without the aid of a large number of people who provided information, encouragement, and assistance.

FOREWORD (CONT'D)

I would like to specifically acknowledge those with whom I have been privileged to work, including Richard Stewart and Frank Hannon of the Strength Branch, Directorate of Airframe Engineering, ASD; C. F. Tiffany and Walter Critchlow, Division Engineering Advisors; and William Geese and Buck Meadows of the B-1 System Program Office who obtained the 2219-T851 aluminum for the specimens. My supervisors in the Strength Branch, B. K. Sanders and Harold Howard, gave me the freedom to develop this project, and Mr. George Riess in the Airlift System Program Office, the time to complete it. The AFML gave me the use of their test equipment, and Gordon Adkins designed the specimen grips.

The fasteners and installation tool were provided by John Ruhl of Huck Manufacturing Company, while J. O. King of J. O. King, Inc., provided cold-working sleeves and mandrels. Kenneth Kulju of Standard Pressed Steel Company allowed me to use the SPS Company Library. Robert Urzi of Lockheed-California Company, and later of the AFML, provided the original list of variables which was subsequently expanded to its present form. Larry Salter of P. B. Fasteners also provided reference material, as did Larry Salinas of Omark Industries.

I had many useful discussions with other industrial, academic, and Governmental colleagues to whom I am indebted. My special thanks go to George Mornhinweg, of Systems Research Laboratories, who drilled and measured all of the fastener holes, installed fasteners, and did much of the testing. James Howard Moore, Elizabeth E. Moore, Gregory Cecere, and Eldred Neubauer also assisted in the fatigue test work. Thomas Zwadony was of enormous assistance in writing the computer programs, as was Virginia Moore in the preparation of the report.

A limited number of copies of the test data are available upon request as Volume II of this report from Dr. C. T. Lynch, AFML/LLN, Wright-Patterson Air Force Base, Ohio 45433.

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SECTION I

INTRODUCTION

1. PURPOSE

The purpose of this dissertation is to determine the influence of hole processing and joint variables on the fatigue life of mechanically fastened shear joints.

2. BACKGROUND

The first major publicity regarding the problem of aircraft fatigue and the role which fasteners play in fatigue came as a result of the 10 January 1954 crash of the British deHaviland Comet jetliner near Elba and the 8 April 1954 crash of the same type aircraft near Naples. These tragic accidents were caused by fatigue failures originating at fastener holes (Reference 1).

Since then, publicity has been given to a large number of aircraft fatigue problems, including: (1) the milk-bottle bolt and fitting on the B-47, (2) B-52 wing and fuselage fatigue problems, (3) F-111 wing carry through structure problems, and (4) the C-5 wing fatigue problem which has caused a safe life limit of 8000 hours to be established for an aircraft whose design life goal was 30,000 hours. These fatigue problems all have a common factor in that failure is expected to come from a crack originating at a fastener hole.

To meet the challenge offered by these problems, a number of "fatigue-rated" or fatigue life enhancing fasteners have been developed and marketed. Some of these have been used for 15 to 20 years with considerable success, but also with considerable cost. Others have had very little application. They vary widely in the way in which they operate, and the results they produce are significantly different. Khol (Reference 2) has listed 37 of these fastener types and has discussed briefly some of the important concepts in fatigue life enhancing fasteners.

These service failures produced requirements for aircraft fatigue testing during development, but very little has been explicitly stated

with regard to fasteners and holes. It was not until the promulgation of specification requirements for airplane damage tolerance that significant statements were made relative to fasteners and fastener holes, as well as their impact on fatigue life (Reference 3).

Unfortunately, no coherent picture of the fastener and joint-related factors which serve to influence fatigue life has been produced, although a number of design manuals have addressed portions of the problem. Predictive models for the fatigue life of a mechanically fastened shear joint need improvement, particularly with respect to manufacturing variables.

While this model development has been done here using only one family of fasteners--Lockbolts--and one type of sleeve cold-working and in one material--Aluminum Alloy 2219-T851, the methodology could be extended to other fastener types and other materials without major difficulty (Reference 4). Additionally, some of the results may be useful in considering design and manufacturing alternatives for some designs which have not yet reached production.

The fastener selected for use in this study was the Lockbolt, a fastener which has had considerable acceptance as an industry standard and which has one of the lowest installed costs of fasteners in the 160 ksi strength class, in the opinion of many aircraft standardization engineers. For similar reasons, the solid sleeve cold-working system was chosen, since its use minimizes the number of manufacturing operations required and results in lower system costs.

Typical fasteners used in this study are shown in Figure 1.

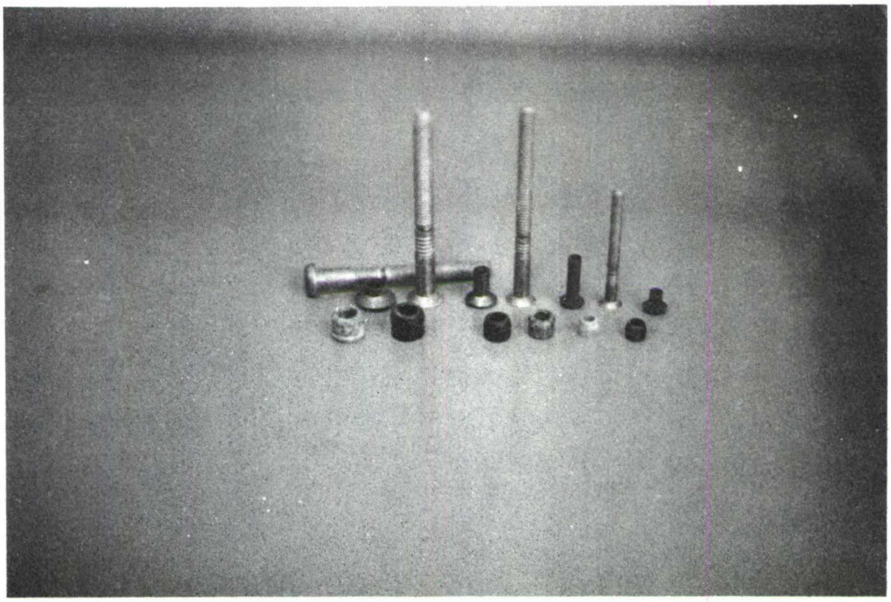

Figure 1. Types of Fasteners Used in this Study

Horizontal in the background is a 5/16-inch diameter protruding head Lockbolt. In the middle row from left to right: a 5/16-inch x 1/4-inch countersink cold-working sleeve, a 5/16-inch diameter countersink Lockbolt, a 1/4-inch x 1/2-inch sleeve, a 1/4-inch Lockbolt, a 3/16-inch x 3/4-inch sleeve, a 3/16-inch Lockbolt, and a 3/16-inch x 1/4-inch sleeve. Front row from left to right: a 5/16-inch tension coining collar, a 5/16-inch tension collar, a 1/4-inch shear coining collar, a 1/4-inch shear collar, a 3/16-inch annealed shear collar, and a 3/16-inch shear coining collar.

SECTION II

DESCRIPTION OF THE EXPERIMENT

1. FACTORS INFLUENCING JOINT FATIGUE LIFE

Urzi (Reference 5) provided an extensive listing of variables which are thought to influence the fatigue life of mechanically fastened shear joints. For this work a shear joint is defined as a joint where the primary load transferred by the fastener is a shear load rather than a tension load. Based on numerous conversations with many individuals in both the aerospace and fastener industries, a more extensive list of possible factors was developed. These factors are described below, along with a brief discussion of each factor and the values which each one took in this series of tests.

a. Load Transfer

The load transferred between sheets in a shear joint depends on the joint design and could range from 0 to 100%. Urzi (Reference 6) recommended three levels of load transfer for standard test specimens in his study of fatigue test standards. These were the no load transfer specimen, a 5% load transfer reversed double dog-bone specimen, and a 100% load transfer lap shear joint. The no load transfer specimen recommended consists of two identical sheets fastened together, the 5% load transfer specimen is as shown in Figure 2, and the 100% load transfer specimen was a single shear lap joint. These specimen designs were considered in selecting the designs used for this test program, and the 5% load transfer specimen, Figures 2 and 3, was used for the 200 low load transfer specimens tested. This specimen configuration has been widely used and seems to give consistent results; yet is sensitive to other variations in joint preparation. The no load transfer specimen recommended by Urzi was not used because it requires two specimen blanks, just as the 5% load transfer does, and given the constraint of only 840 specimen blanks, a single sheet configuration, Figures 4 and 5, was used instead. Urzi's lap shear 100% load transfer configuration has been shown by Ford (Reference 7) to be difficult to

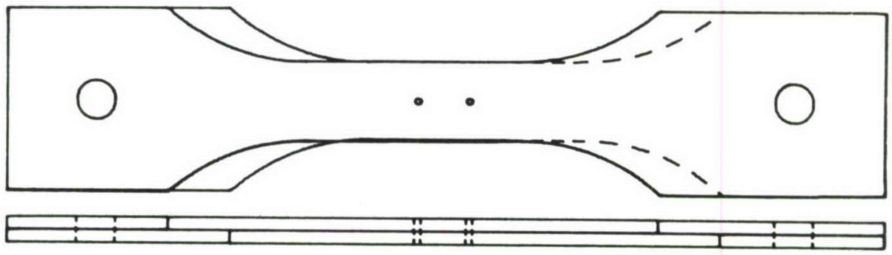

Figure 2. 5% Load Transfer Specimen

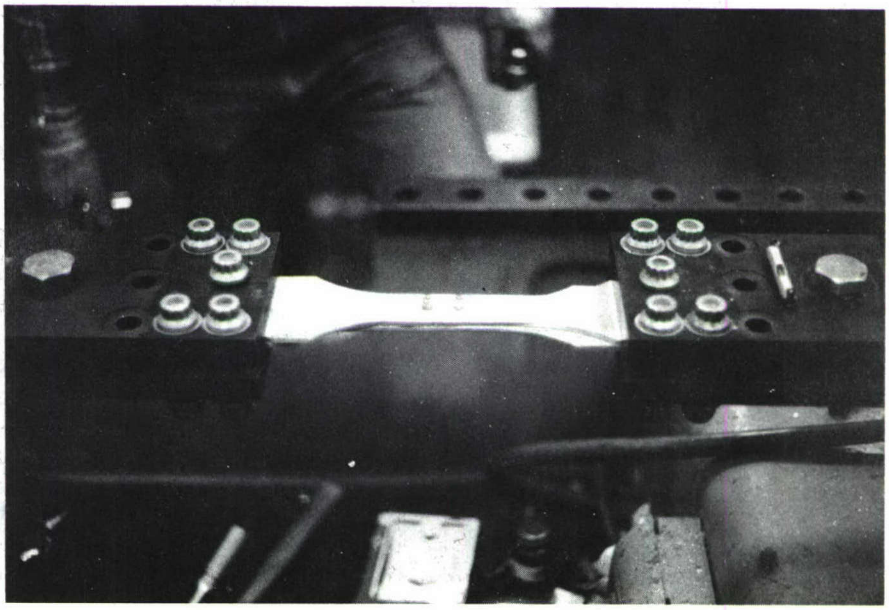

Figure 3. 5% Load Transfer Specimen Installed in Test Machine

The technician holds two wrenches, as he has just finished tightening the 8 3/4-inch bolts around the edge of the specimen grips and prepares to check the specimen for level installation.

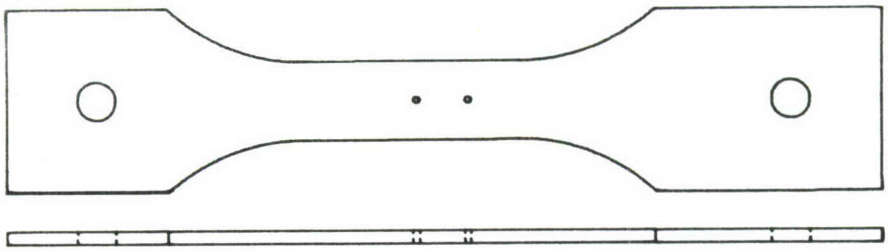

Figure 4. Zero Load Transfer Specimen

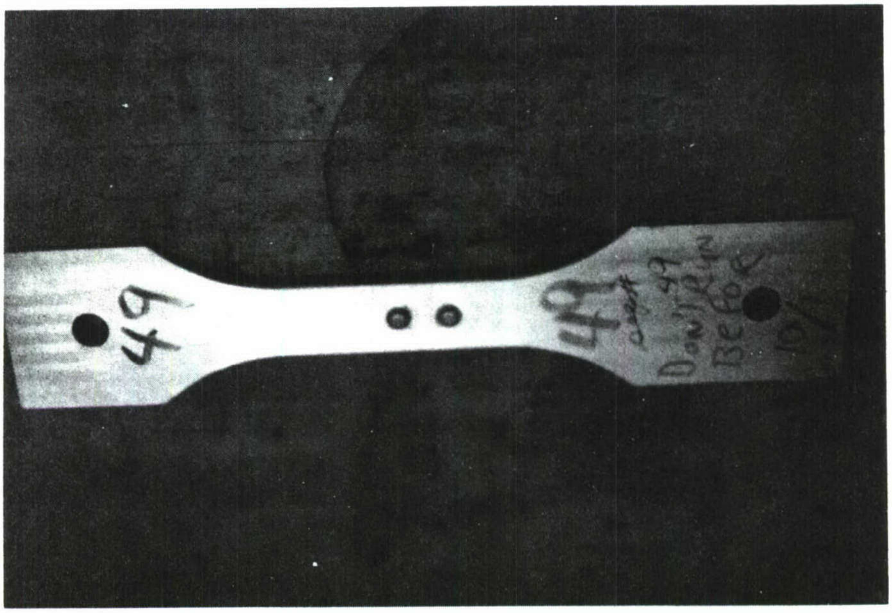

Figure 5. Zero Load Transfer Specimen with Protruding Head Fasteners

The "Don't run before 10/1-inch annotation was made to ensure that the primer around the fasteners had at least six weeks drying time. When the specimen broke, the primer was still fluid enough to have migrated into the fatigue crack.

adequately restrain in order to avoid bending. Therefore, the double-lap shear joints, Figures 6 and 7, which bear a similarity to the 100% load transfer specimens employed successfully by Tiffany, Stewart, and Moore (Reference 8) were used in a previous program. Additionally, a 50% load transfer, 1-1/2 dog-bone configuration, Figures 8 and 9, was used for some testing. While Urzi (Reference 9) concluded that this specimen was not adequately sensitive to differences in fasteners and other joint variables, variants of this specimen have been used in many previous test programs.

For this series of tests 80 no load transfer specimens, 200 low (5%) load transfer specimens, 80 medium (50%) load transfer specimens, and 120 high (100%) load transfer specimens were assembled.

b. Stress Level in Material Fastened

The design stress level of the material fastened in a joint is one of the prinicpal variables available to the designer in his work. In most joints considerable attention is given to the stress level in the fastened material. Most vehicle structural joints have expected lifetimes which range between 1000 and 100,000,000 load cycles. The range of lifetimes of greatest interest in aerospace design is between 10,000 and 1,000,000 cycles. In general, there is greater variability in long life testing, but the greater time and expense involved in high cycle fatigue testing makes this testing less frequently attempted. For this series of fatigue tests, a nominal gross stress of 30.7 ksi was chosen. This is approximately the same gross stress level that has been used in several other fastener test programs and usually yields failures from 10,000 to 1,000,000 cycles in relatively high strength aluminum alloys.

c. Stress Ratio "R"

The stress ratio, "R," where

$$\text{"R"} = \frac{\text{minimum cyclic stress}}{\text{maximum cyclic stress}}$$

does influence fatigue life. Ford (Reference 10) noted that most joint fatigue testing has been done at "R" = 0.1 and hypothesized that this

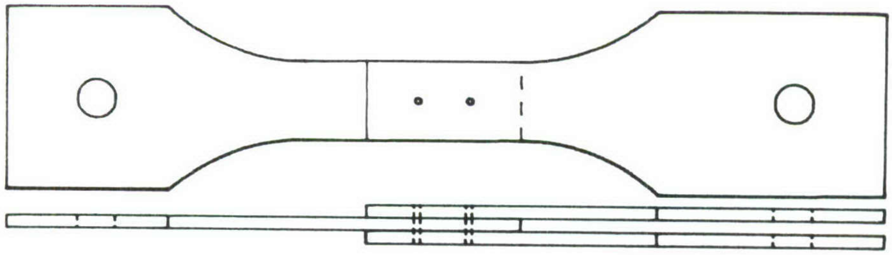

Figure 6. 100% Load Transfer Specimen

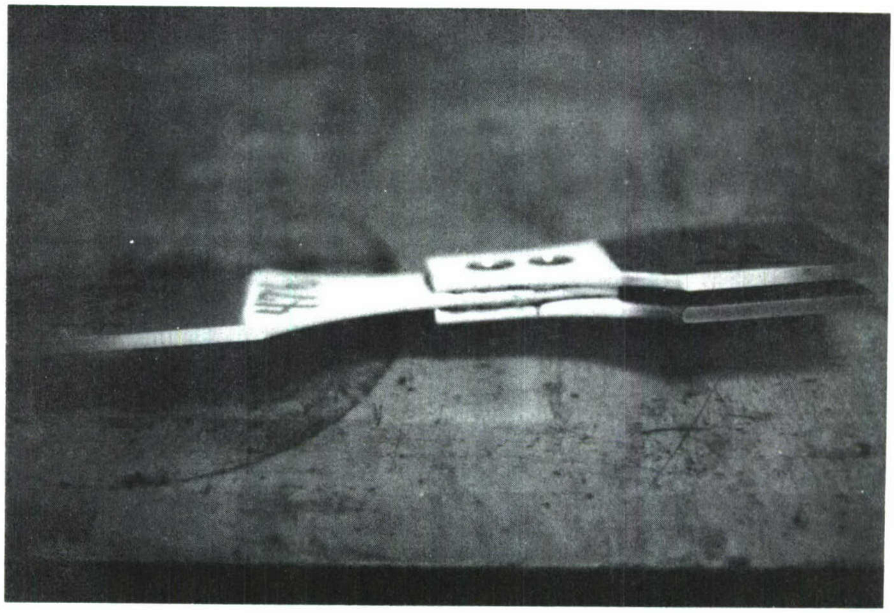

Figure 7. 100% Load Transfer Specimen Plus Chemical Coating

Figure 7. This 100% load transfer specimen has received the chemical conversion coating, primer application, and polyurethane top coat. It had sealant in its faying surfaces. Note that the countersinks had been drilled much more deeply than necessary for flush installation of the fasteners.

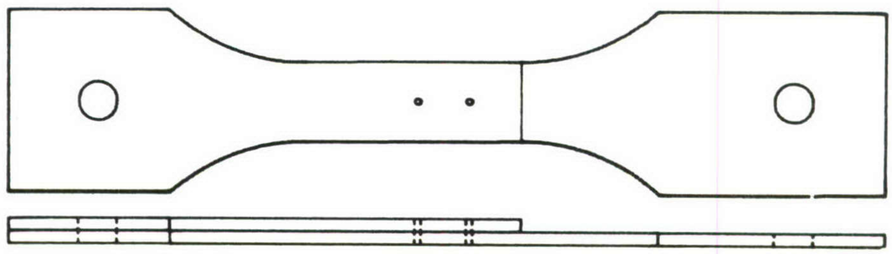

Figure 8. 50% Load Transfer Specimen

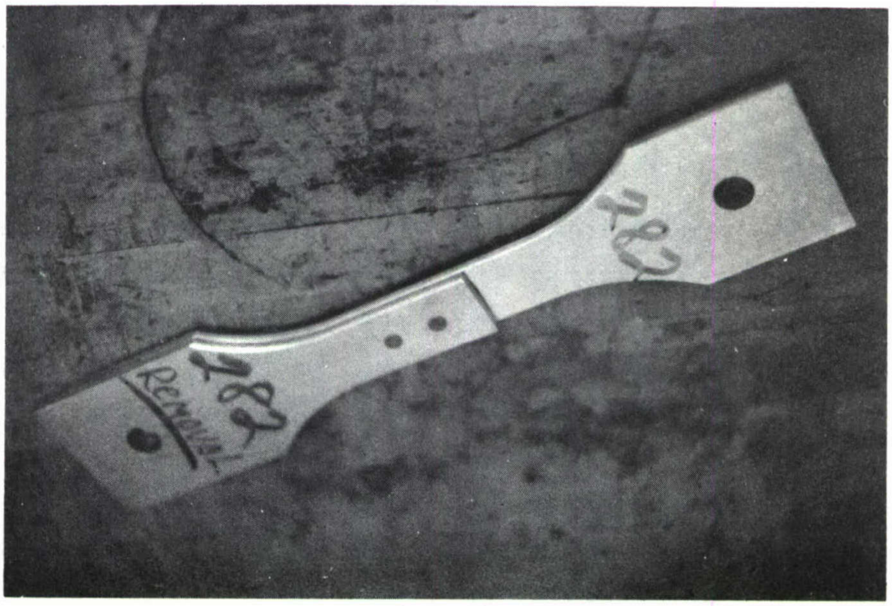

Figure 9. 50% Load Transfer Specimen

Figure 9. Note that the sequence number has been marked on both ends of the specimen and that this specimen is scheduled to have its fasteners removed and reinstalled during the test. Flush (Countersink) fasteners have been installed in this specimen.

was done because most early (constant amplitude) fatigue machines ran well at this stress ratio. In addition, by running at positive "R" values, the tester avoids the problems of constraints which are necessary to prevent buckling of the specimens. Ford also shows that the "R" ratio can be incorporated in the stress parameter by the relationship

$$\text{stress parameter} = (\sigma_{max} \sqrt{1-R})$$

and all testing is reported here using this stress parameter. All testing done during these experiments was planned for an "R" of 0.1. However, any deviations from this value were recorded and included in the computations.

d. Physical Environment

The physical environment to which a joint is exposed can radically influence the fatigue life of that joint. These effects have been discussed by Uhlig (Reference 11). Fontana and Greene (Reference 12) have also pointed out that in ordinary fatigue the cyclic rate has a negligible influence in fatigue resistance. However, corrosion fatigue is most pronounced at low frequencies. Because corrosion is a time dependent, electrochemical reaction, fatigue testing at high cyclic rates is not suitable for evaluating this problem. While actual structural joints may be exposed to significant corrosion, testing this sensitivity of fastener and joint-related variables to corrosion was outside the scope of what could be accomplished within the time available for testing. All testing was done in the ambient laboratory environment. In conjunction with testing of each specimen, the wet and dry bulb temperatures were recorded, and the relative humidity was computed from the Psychrometric Tables (Reference 13). While no effort was expended in trying to control the temperature or humidity, significant variations were noted.

e. Countersink Depth to Sheet Thickness Ratio

A large number of fasteners used on aircraft require countersink holes and are installed flush with the surface on the head side. Sines

and Waisman (Reference 14) show that as the countersink depth approaches the thickness of the material under the head of the fastener, the stress concentration factor, K_t, increases from the range 2 - 4 to the range 8 - 10 (Figure 10). The condition where the countersink is deeper than the thickness of the top sheet produces a "knife edge" or "feather edge" condition, and warnings concerning this condition appear in the Design Handbooks (Reference 15). In order to assess more accurately the extent to which the countersink depth would modify the fatigue life of the specimens, the 240 specimens having flush head fasteners installed were divided into four equal groups. The first of these groups had no countersink drilled, but flush head fasteners were installed. The second group had the countersink drilled to one half its normal depth. In the third group the countersink was drilled to its normal depth. The fourth group had the countersink drilled to 1.5 times its normal depth.

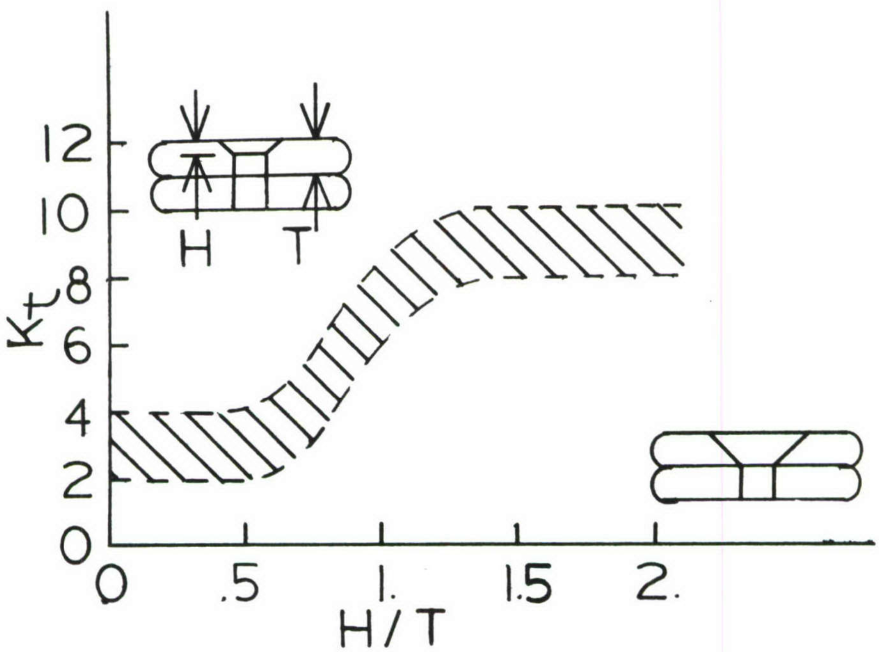

Figure 10. K_t vs. H/T

As the countersink depth "H" increases relative to the sheet thickness "T", the K_t increases. In the lower right corner a knife edge condition is shown. This corresponds to H/T = 1. Adapted from Spaulding, "Detail Design for Fatigue," p. 332.

f. Sheet Material

For aerospace structures, metallic members are usually aluminum, titanium, or steel alloys. The material chosen for these tests was the Aluminum Alloy 2219-T851. Chemical analysis of a sample of this material was performed by the Air Force Materials Laboratory, and its composition was determined to be:

Cu	6.2%
Si	.07
Mn	.25
Fe	.13
Zr	.11
V	.05
Ti	.02
Mg	.01
Al	balance

This chemical analysis meets the requirements of MIL-A-8920. The "A" (Reference 16) longitudinal mechanical properties for the range .250- to 1.000-inch thickness, as given in Military Handbook 5, (Reference 17) are:

Ultimate Tensile Strength	62 ksi
Tensile Yield Strength	47 ksi
Compressive Yield Strength	48 ksi
Shear Ultimate	37 ksi

The Damage Tolerant Design Handbook (Reference 18) does not show an apparent toughness for this material in the quarter-inch thickness. However, in the 0.125-inch thickness, the $K_{(apparent)}$ in the L-T direction is shown as 45 ksi-sqrt inches, and in the 1.000-inch thickness the $K_{(app)}$ in the L-T direction is 64 ksi-sqrt inches. While in many joints more than one material may be fastened together, these tests will use only this one material.

g. Stack-up Thickness to Shank Diameter Ratio

The stack-up thickness to fastener shank diameter ratio for most engineering structures will be between .5 and 10, where the stack-up thickness is the total thickness of the material fastened. With the use of three fastener diameters (nominally 3/16, 1/4, and 5/16 inch), the ratio will range from .80 to 1.33 in the zero load transfer specimens. In both the 5% and 50% load transfer specimens, the ratio will be between 1.6 and 2.667. With the 100% load transfer specimens, the ratio will be between 2.4 and 4.00. These variations will allow some further quantification of Urzi's (Reference 19) statement that as the thickness to diameter ratio increases, the fatigue life decreases.

h. Type of Loading

In determining the fatigue life of a joint, the loading spectrum to which the joint is exposed is extremely important. Most fatigue testing of small scale components, such as simple joints like those used in this series of tests, has been done using constant amplitude machines. However, for larger scale component tests, constant amplitude fatigue testing is inadequate, and spectrum loading is introduced. Spectrum loading is frequently done using servo-controlled test equipment coupled to digital computer systems for monitoring, controlling, and recording the loads. This arrangement allows testing structural components to loads predicted on a flight by flight basis, and in some cases allows the introduction of "random" loads from a predicted probability distribution for the loads. While this testing more accurately simulates the air vehicle's flight loading, it has the very real disadvantages of being considerably slower (typically an order of magnitude slower than constant amplitude fatigue testing) and several times more expensive per test hour than constant amplitude testing.

When spectrum fatigue testing is done, there are two basically different spectra which are used: (1) a maneuver spectrum typical of fighter or attack aircraft where the majority of the loads are a result of aircraft maneuvers and (2) a gust load spectrum where the primary loads result from random gust loading of the aircraft and from the

ground-air-ground cycle which occurs on each flight. The latter spectrum is typical of the loading which a transport aircraft receives. Within these general spectrum categories, the precise loading sequence is developed for a particular point on the aircraft. As a result, there is no single "standard" spectrum which would be suitable for materials characterization testing.

All of the testing for this program will be constant amplitude testing accomplished on the 20-ton Schenck Fatigue Machine at the Air Force Materials Laboratory, Wright-Patterson AFB, Ohio. Constant amplitude fatigue testing has been recommended by Ford (Reference 20) for the development of MIL-HDBK 5 design data for fatigue improvement fasteners.

i. Sealing

Sealants are used to produce fluid tight joints. Most sealants are polysulfide or corrosion inhibiting polysulfide base materials. While many fastener systems, particularly interference fit fastener systems, do not allow fluid transfer through the fastener hole, the inside of fuel tanks are coated with sealants, the faying surfaces of joints in fuel tanks are assembled with sealants and the exterior surface joints of aircraft are assembled with sealant in the faying surface. Thus, in a significant number of joints in an aircraft, sealant is present, but little has been done to quantify the influence of this material on the fatigue life of joints. For this program 100 of the 5% load transfer, 40 of the 50% load transfer, and 60 of the 100% load transfer have a layer of MIL-S-8802 (Reference 21) sealant in the faying surface.

j. Sheet Corrosion Protection

The sheet materials being fastened may have various amounts of corrosion protection. In Air Force aircraft the requirements of MIL-STD-1568 (Reference 22) apply to the finish systems used on the structure. While there are some limited applications for bare aluminum, 2000 series aluminum alloys are normally given an initial anodizing treatment or a chemical film treatment in accordance with MIL-C-81706

(Reference 23). The chemical film treatment is commonly called alodyning. Following this initial treatment, most structures are coated with an epoxy primer (Reference 24) and many surfaces will also be covered with a polyurethane top coat (Reference 25). To show the changes in fatigue life which these finish systems could induce, 120 of the specimens were left bare, 52 received only the alodyne treatment, 240 had the chemical conversion coating applied and then had one coat of epoxy primer applied, and finally, 68 specimens were finished with the chemical conversion coating, the epoxy primer, and a top coat of polyurethane.

k. Fretting Protection

Hoeppner and Goss (Reference 26) defined fretting as the damage which one or more surface(s) may undergo when two surfaces are held in contact by a normal load and undergo small relative displacement. The surfaces held in contact are called the faying surfaces. Sandifer (Reference 27) has pointed out that fretting has been noted in aircraft failure areas by several investigators. He also stated:

> Analysis of a number of failures occurring in airframe joints indicated that in a larger percentage of the cases failure occurred away from the fasteners at the sheet interface in a region of heavy fretting. This was particularly true for joints utilizing high strength interference fit fasteners, which due to their higher clamping pressures moved the faying surface skip front, which produces fretting, more distant from the fastener. Thus the benefits to be derived from new fastener systems and hole preparation techniques are severely limited unless fretting fatigue failures are eliminated.

The solution to this problem is not simple. O'Neill and Smith (Reference 28) have shown that a water displacing, oil-base penetrant, commonly used in airline service to combat corrosion, reduced the fatigue life of a riveted lap joint by 33 to 50%. Lubrication also has been shown by Perry (Reference 29) to significantly reduce the static strength of riveted lap joints. Sandifer showed the use of the correct shim material could prevent premature fretting, while Melcon and Moss demonstrated excellent results in fatigue life enhancement of joints through adhesive bonding (Reference 30).

For this test program, in addition to the sealing and finish systems described previously, 12 specimens had petroleum as a lubricant in the faying surface, and 40 specimens had an aluminum-filled two-part epoxy adhesive in the faying surface. No shim materials were used during this evaluation, although corrosion resistant steel or Micarta plastic shims are used in some aerospace applications when aluminum structural elements require shimming.

l. Paint/Primer Thickness

The number of coats of primer or top coat are usually specified for specific structural areas of aircraft. For military aircraft these specifications are given by MIL-F-7179 (Reference 31). The paint thicknesses may vary with structural location, and local part geometry can also cause variations in coating thickness. Since the test specimens used for this program were all of one basic design and were coated before assembly, there was no reason to expect significant differences in coating thickness. The thickness of the coatings was measured on several specimens, and no variation was detected for similar coatings. The value of the coating thickness was recorded for each type of coating.

m. Gap Between Sheets

In almost any structural assembly, gaps can be expected between the sheets of fastened material. These gaps may be caused by a large number of factors, such as: (1) lack of tolerance control, (2) burrs from drilling between the faying surfaces, (3) lack of adequate clamp-up during drilling or assembly, or (4) lack of fastener preload. These gaps reduce or preclude load transfer through friction between the fastened sheets, forcing the fastener to carry more load than it would do otherwise. Additionally, these gaps may cause early failure of the fastener by increasing the shear loads in the fastener or by causing the fastener to bend (pin bending). No gaps were intentionally created during this test program. However, for each specimen the measurement was made midway between the two fasteners using a feeler gage to check for any gap between the two sheets.

n. Test Temperature and Humidity

The test temperature, particularly if the temperature reaches a value high enough to cause a metallurgical change in the material, can influence the results of a fatigue test. Thermal cycling can cause thermal fatigue if significant temperature changes take place. This test series was conducted in an air conditioned laboratory, so only small thermal variations were expected. However, during the testing the laboratory air conditioning system broke down, and thus relatively warm conditions were encountered for a number of tests. The air temperature in the test room was measured by a recording wet and dry bulb thermometer located approximately ten feet from the test specimen, and this temperature was noted at the beginning of each test (Figure 11).

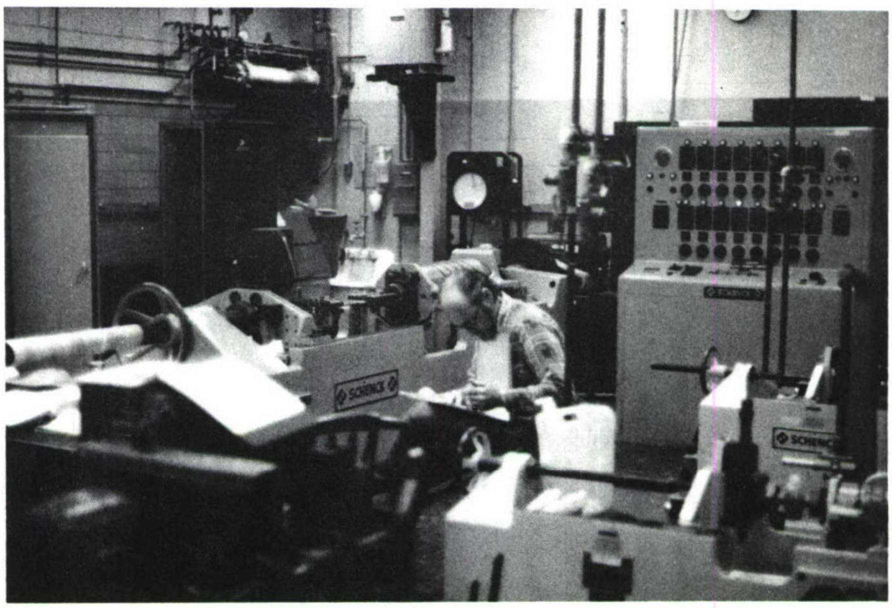

Figure 11. Test Machine Setup

The 20-ton Schenck Fatigue Machine is shown during a test. The round instrument above the technician's head is the recording dry and wet bulb thermometer.

o. Edge Distance/Diameter Ratio

The ratio of edge distance divided by hole diameter is one which provides useful information about the joint. As used in this study, and in many other works on joints, the edge distance is defined as the distance from the hole centerline to the nearest edge of the sheet material and is symbolically: "e." The hole diameter is shown as: "d." As the ratio e/d increases, the fatigue life of a joint normally increases. Jeffery (Reference 32) has demonstrated that in the case of a circular hole near the straight boundary of a semi-infinite plate under tension parallel to this boundary, the stresses in the plate section between the hole and the edge of the plate become a large multiple of the average plate tensile stress as the distance between the hole and the edge becomes smaller. Timoshenko and Goodier (Reference 33) showed that the stress at the edge of the hole is the peak stress until

$$e = \frac{d}{2}\sqrt{3}$$

at which point the stress at the edge of the plate equals the stress at the edge of the hole. If e is further reduced, the peak stress is at the edge of the plate.

In most applications in fatigue, critical structure designers attempt to keep the e/d ratio greater than 2. The specimens used in this study were sized to have an e/d of 3, when used with a 1/4-inch fastener. While this would represent a greater than typical edge distance, it also was selected to provide significant information for determining differences between fasteners and fastener types during screening tests. With 5/16-inch fasteners, the e/d ratio is approximately 2.25, while the 3/16-inch fasteners, it is about 4.0.

The edge distance was determined by measuring the distance from the edge of the hole to the edge of the test plate and then adding the radius of the fastener hole. Within the range of e/d ratios used for these tests, relatively little variation in fatigue life as a function of e/d ratio was expected.

p. Hole Roughness

The surface roughness of parts is normally significant in fatigue testing. Juvinal (Reference 34) showed the influence on fatigue life of a number of different surface finishes and pointed out that smoother surfaces generally lead to longer fatigue lives. While many industry standards currently specify maximum values for surface roughness in fastener holes, Ford (Reference 35) did not reach a conclusion on the influence of this factor on fatigue life in his study of interference-fit fasteners.

For this series of tests fastener holes were prepared in four ways: (1) by drilling and reaming, (2) by drilling, (3) by abusively drilling, and (4) by intentionally roughening. One—fourth of the specimens were prepared by each method. A target diameter, corresponding to a standard drill size, was established for each hole. The reamed holes were drilled one size undersized, and then a four-flute reamer was used to finish the hole to the specified size. Drilled holes were prepared by drilling with a standard size drill of the target diameter. Roughened holes were drilled with a drill which had been intentionally dulled and which had been specially ground with negative angles. In addition, the drills were forced into the specimens at the highest feed rate which could be achieved without stalling the drill press motor. Abusively drilled holes were prepared in a similar manner, except that the drills were segregated for abusive handling and the drill cutting surfaces were intentionally subjected to mechanical abuse including hammering. No target surface roughness values were established. However, the machinist preparing the holes was instructed to use an ordinary degree of care with the normally drilled and reamed holes and was encouraged to be agressive in his drilling of the roughened and abusively drilled holes. The condition of the holes was measured on a Tallysurf surface measurement instrument. The surface roughness was measured along the holes and was reported as a single average reading for each hole.

Since the hole countersinking operation for flush head fasteners was done on a small bench mill and since considerable effort was made to achieve the desired depth of countersink and countersink offset, no

roughened or abusively drilled countersinks were produced. The countersink surface finish was approximately 32 microinches in all cases and showed no measurable variation.

q. Hole-Countersink Concentricity

If the hole and the countersink are not drilled in a single operation, it is possible for the hole and countersink to have different longitudinal axes. This nonconcentricity creates eccentric loading in both the fastener and in the sheet material. In order to determine whether this nonconcentric condition changes the fatigue life of the specimens, 28 of the countersinks were drilled offset 1/8 of the hole diameter from the hole centerline, and 36 specimens had the countersinks drilled offset 1/4 of the hole diameter from the hole centerline. The countersink offset was normal to the longitudinal axis of the specimen.

r. Hole and Countersink Perpendicularity

The deviation of a fastener hole from perpendicular to the local surface can cause excessive head bending moments and failure of the fastener head. It can also cause galling and deformation of the sheet metal surface under the fastener head; and also can lead to failure away from the fastener shank from cracks originating at stress concentrations caused by the uneven fastener head contact. Thirty-six specimens had the fastener holes drilled 2 degrees from perpendicular to the sheet surface, and 36 specimens had holes drilled 4 degrees from the sheet surface. Additionally, 40 specimens had the countersinks drilled 2 degrees from perpendicular to the sheet surface, and 40 specimens had the countersinks drilled 4 degrees off perpendicular. When specimens were selected for both hole and countersink to be off perpendicular, they were drilled off in opposite directions.

s. Hole Taper

The correct hole taper angle is essential for the proper functioning of some fastener systems, such as Taperloks (Reference 36). For straight shank fastener systems, however, straight holes are

assumed. If the hole is not straight, the amount of clearance or interference between the fastener and the sheet material would vary, and a joint of reduced stiffness would result.

For this test program 24 specimens were selected and a target hole taper of 1 degree was established for them. An additional 24 specimens were to have a target hole taper value of 2 degrees. These 48 specimens were drilled with a hand-held drill, and the drill was intentionally moved during drilling to generate a tapered hole. All specimens, however, had the hole diameter measured at both the top and bottom of the holes. These diameters, D_1 at the top of the hole and D_2 at the bottom of the hole, were used along with the specimen thickness, T, to determine the hole taper angle α.

$$\alpha = \tan^{-1} \left(\{D_2 - D_1\}/\{T-H\} \right)$$

where H is the depth of the countersink. Even though only 48 intentionally tapered holes were drilled, both abusively drilled and intentionally roughened holes tended to have noticeable taper.

t. Interference Level

Fastener interference (or clearance) is the difference between the hole diameter and the fastener diameter. If the fastener is larger than the open hole, then an interference condition exists when the fastener is installed. The simplest and most commonly used interference fit fastener is the rivet, even though it is usually used without recognition or understanding of its role in fatigue life enhancement (Reference 37). To ensure maximum interference in the rivet countersink area, Albert Sherman's procedure for installing flush rivets flush to high with respect to the structure is used by all aircraft industries throughout the world (Reference 38). This procedure provides better hole and countersink fill by the rivet and significantly enhances joint life. Conventional riveting procedures are difficult or impossible to use with steel or titanium rivets having strengths in the 160 to 180 ksi range. High velocity metal forming tools, such as the Stress Wave Riveter, have been developed which will allow high strength rivets to be driven to interferences of more than 0.01 inches (Reference 39).

Smith (Reference 40) has also commented on the importance of interference in enhancing fatigue life, demonstrating the fatigue life improvements achieved with several types of interference fit fasteners. While there is considerable evidence that increasing interference produces longer fatigue life, there is also evidence which indicates that there is a maximum interference which should be used, as well as the fact that increasing interference beyond this value results in a decrease in fatigue life from the maximum value. This increase in fatigue life occurs because the residual hoop tension near the hole reduces the stress variations on the metal next to the hole. Since the region adjacent to the hole is the area which usually cracks first, the change in stress state variation results in longer fatigue life. Lindh (Reference 41) showed peak lives depending on both the material (aluminum alloys 2024 and 7075) and the fastener systems used (2217 slug rivets, Ti Rivbolts, Hi-Tigue fasteners and Taper-Lok fasteners).

The experiment for this study was designed so that 25% of the fasteners were to be installed in clearance fit holes; that is, the holes were to be larger than the fastener diameter. Twenty-five percent of the fasteners were to be installed in transition fit holes; that is, holes which were drilled to the nominal fastener diameter. Twenty-five percent of the fasteners were to be installed in low interference holes; holes where the hole diameter was less than .005 inches less than the nominal fastener diameter. And finally, 25% of the specimens were to have the fasteners installed in high interference holes; holes which were more than .005 inches smaller than the nominal shank diameter.

The actual interference, I, was computed after the diameter at the top of the hole, D_1, and the bottom of the hole, D_2, were subtracted, respectively, from the diameter of the fastener at the same locations, d_1 and d_2 respectively, and the differences averaged. A negative value of I represents the average clearance between the fastener and the hole.

$$I = \frac{(d_1 - D_1) + (d_2 - D_2)}{2}$$

The interference level was determined for each fastener.

u. Hole Cold-Work

The hole may be cold-worked by passing an oversized tapered mandrel through the hole. The hole walls may be protected from the mandrel by a sleeve, or the mandrel may be lubricated to reduce the force level required to pull the mandrel through the hole and to protect the sides of the hole.

Cold-working the hole produces a residual compressive stress field around the hole and tends to blunt any cracks or flaws which may have been present in the hole. Cold-working fastener holes has been proven very effective in increasing the fatigue life of a precracked specimen in work reported by Petrak and Stewart, as well as by Tiffany, Stewart and Moore (Reference 42). Lindh (Reference 43) also noted the effectiveness of cold-working holes for fatigue life enhancement in his study.

There are three significant variations to the process of cold-working a hole. Speakman (Reference 44) described the process of putting an oversized tapered mandrel through the hole as a step in the stress coining procedure. The hole is plastically deformed by driving the lubricated expansion pin through the undersized hole. He demonstrated significant fatigue life improvement in both aluminum and steel parts using this system.

Phillips (Reference 45) provided an extensive description of the split sleeve cold-working system. Key process steps include: (1) drilling an undersized hole, (2) placing a lubricated corrosion resistant steel sleeve in the hole (this sleeve is slit longitudinally to facilitate removing it from the hole), (3) pulling an oversized tapered mandrel through the sleeve to expand the hole, (4) removing the split sleeve from the hole, and (5) reaming the hole to its final size. The final reaming step is needed not only to size the hole, but also to smooth out the impression the split in the sleeve leaves in the sides of the hole.

King (Reference 46) has developed a cold-working system in which a cylindrical lubricated sleeve is placed in the hole and a tapered

mandrel is pulled through the sleeve. The sleeve remains in the hole and acts as a bushing between the fastener and the hole sides. This system avoids the final reaming operation required with the split sleeve system, and yet Petrak and Stewart (Reference 47) show equivalent life enhancement from the two systems.

Other means of cold-working holes include shot-peening, Roto-peening, and roller burnishing. These techniques all induce residual compressive stresses and have found some commercial success.

For this series of tests the solid sleeve cold-working system was chosen. King (Reference 48) developed a series of mandrels sized in increments of 0.001 inches and tables showing the final hole size expected, given the initial hole size and the mandrel size used. Furthermore, since fewer processing steps are required, the total time and cost for the fastener installation tend to be lower.

Of the 480 specimens 320 received no cold-working. Eighty of the specimens received low cold-working; that is, they had approximately one half the cold-working which Potter and Grandt (Reference 49) suggested as optimum for life improvement. The final 80 specimens were planned to receive approximately the optimum cold-work proposed by Potter and Grandt.

The cold-work for each hole was determined by measuring the diameter of the hole after it was drilled or reamed. The sleeve was then inserted in the hole, and the mandrel was pulled through the hole. The diameter of the hole was then measured. Since the sleeve wall thickness was 0.008 inches, 0.016 inches (the two wall thicknesses) was added to the second diameter measurement, and from this sum the original hole diameter was subtracted to obtain the cold-work in terms of diameter expansion.

v. Fastener Shank Contact

Fastener shank contact is an indirect measure of both the hole surface roughness and interference. Tapered shank fasteners, such as Taper-Loks, allow for the gaging of this parameter prior to fastener installation. To gage shank contact for these tapered fasteners, either

a gage pin or a segmented capacitor gage can be used. The former is coated with a dye, such as Prussian Blue, inserted in the hole, and gently tapped. When the pin is removed from the hole, the pattern of dye remaining on the pin indicates the amount of shank contact. This gaging method can be employed to detect rifling or tool marks in the hole, as well as out-of-round conditions, and can also give an indication of surface roughness. In the instance of the segmented capacitor gage, this instrument is inserted in the hole and the parameters are gaged electronically. Unfortunately, for straight holes, equivalent gaging has not been developed.

Fastener shank contact was determined after specimen failure by examining the fastener and the hole where the failure occurred. Visual inspection of the fastener and hole revealed changes in the appearance of the surfaces where they had come in contact. Upon completion of this examination of the components, the fastener shank contact was estimated. In some cases, such as when fasteners were installed in holes with significant clearance so that no shank contact occurred, or when they were installed in high interference holes and examination of the failures showed complete contact, the shank contact of the other hole was estimated without inspection of the hole. In some of the 5% load transfer specimens, the sheet failure occurred in the top sheet at one hole and in the bottom sheet in the other hole. In these cases the shank contact in both holes could be determined.

No target values for shank contact were established. However, whenever possible, shank contact determinations were made after failure.

w. Hole Clean-up

After the fastener holes have been drilled, entry and/or exit burrs may exist in the sheet material. These burrs can act as stress concentrators and can become failure initiation sites. In fatigue critical areas burrs are normally removed to the extent possible. In complex or large assemblies, it is not usually possible to destack and deburr the individual parts after the holes have been drilled. However, simple parts are occasionally destacked and deburred.

For this series of tests 240 of the specimens were not deburred. Burrs present were allowed to remain and were moved only to the extent necessary to insert the fastener in the hole. The other 240 specimens had both entry and exit burrs removed to the extent possible with a hand-held file and a hand-held countersink.

x. Fastener Material and Strength

Aerospace structural fasteners are commonly made of aluminum, titanium, or steel, and thus are available in ultimate tensile strengths ranging from about 55 to about 300 ksi.

Lindh (Reference 50) found no dependence on fastener material (aluminum or titanium) in upset fasteners used in his fatigue studies. On the other hand, Ford (Reference 51) found joints with titanium fasteners exhibited much more scatter in fatigue life than did joints using steel fasteners.

With the data available the influence of fastener material or material strength level on fatigue life is not clear, and unfortunately, since only one material (an alloy steel) in one strength range was used in this testing, the effect of this factor could not be evaluated on the basis of this work.

y. Fastener Corrosion Protection

Fasteners may have any of several corrosion protection systems applied to them. Titanium and corrosion resistant steel fasteners usually do not have any corrosion protection, other than surface passivation, unless they are used on the outer surface of an aircraft, in which case they usually are installed with either a wet primer in the hole or with a wet sealant material. These materials are used primarily to reduce corrosion in the sheet material fastened. Aluminum fasteners are usually anodized to reduce their sensitivity to corrosion and may be wet installed, if they are used in an exterior environment. Alloy steel fasteners are usually cadmium plated although they may have chromium, nickel, or aluminum platings. Furthermore, they may be installed wet if used in an exterior location.

The fasteners used in these tests were plated with 0.0002 inch cadmium, by the supplier. In addition, 240 of the specimens had the holes painted with zinc chromate primer (Reference 52) immediately before fastener installation. While much of this primer was wiped out of the holes by the fasteners which were in interference, even high interference cases showed some primer remaining in the hole when the failed specimens were examined.

z. Nut/Collar Material and Strength Level

Just as there is considerable variation in fastener material and strength level, there is similar variation in nut or collar material or strength level. Nuts or collars intended for use in tension application are designed to develop the full tensile strength of the bolt. However, the actual strength level of the nut material may be somewhat less than that of the bolt and this condition can still be met. Where the principle load on the fastener will be in shear, the nut or collar does not have to be as strong, and to save weight it is frequently made of lighter, lower strength materials, such as aluminum, even though the bolt material is steel or titanium.

The collars used for these tests were aluminum. The fasteners for 384 specimens were installed with collars of 2024-T4. Forty-eight specimens were installed with collars which had been annealed to the 2024-0 condition. An additional 48 specimens had the fasteners installed with no collars.

aa. Nut/Collar Configuration

Nuts and collars both serve to hold the bolt in place. However, they differ in one major respect: nuts are threaded and generally reusable while collars are not threaded and are swaged on to grooves on the bolt. Since they undergo plastic deformation during installation, they are a one-time use item, and if they have to be removed, they must be cut off of the bolt. Lockbolts were used for all specimens and require collars rather than nuts.

Most nuts or collars have bearing faces which are essentially flat. Nevertheless, both nuts and collars are available in coining configurations. Coining collars have bearing faces which are conical. During installation these collars make initial contact with the sheet material next to the fastener shank (at the edge of the hole) and thus produce higher loads in the sheet material next to the hole than they do at the edge of the collar. Ninety-six of the specimens tested had coining collars installed.

bb. Fastener Preload

Fastener preload, or the clamp-up exerted by the fastener on the fastener material, influences the way in which the load is transferred from sheet to sheet in the joint. Nestorenko (Reference 53) has shown that there is an experimental method for developing the optimum preload for bolts when used with rivets in structural joints. This optimum is found by varying the amount of load being transferred through the bolt relative to the amount of load being transferred through the friction developed in the fastened plates, as a result of the preload established in the bolts.

Preload is needed in tension joints to prevent sheet separation at high loads. If sheet separation occurs, a radical decrease in fatigue life would result from the impact loadings. Similarly, in shear joints preload prevents sheet separation and aids in reducing sheet bending under eccentric loading conditions. In addition, preload allows frictional load transfer between the sheets fastened. The amount of load transferred in this manner depends not only on the fastener preload but also on the coefficient of friction between the two sheets. This helps to explain the fatigue life improvement noted in joints where an adhesive has been put in the faying surface. The adhesive effectively increases the coefficient of friction between the two sheets. Similarly, the decrease in fatigue life noted in lubricated joints may be at least partially caused by the decrease in friction between the two sheets and the resultant reduction in the load which is transferred as a result of the preload. This forces more load through the fastener and results in higher stresses being induced in the sheet material by the fastener leading to earlier failure.

For this series of tests, the preload was varied by the use of different collars on the fasteners. Ruhl (Reference 54) has determined the preload that is developed in each diameter fastener used by each of the collar types used. His results are summarized in Table 1. The values shown are the average of five tests run on each of the collar types and diameters shown. The values listed in Table 1 are averages and were developed for fasteners in clearance holes. Therefore, they do not represent the clamping force between the sheets for fasteners installed in high interference holes. However, since the clamping force for fasteners in interference fit holes would vary with the amount of interference, and would be almost impossible to obtain, the tabulated values will be used for all cases. When the fasteners are double-driven (that is, they are first drawn fully into the hole without the collar present and then the collar is installed), these values approximate the load in the fastener just under the collar.

TABLE 1

FASTENER PRELOAD IN POUNDS FOR VARIOUS COLLAR TYPES

Collar Type	Nominal Fastener Diameter		
	3/16"	1/4"	5/16"
None	0.	0.	0.
Annealed Shear	598.	1208.	2712.
Shear	788.	1554.	3830.
Shear Coining	808.	1484.	2746.
Tension	1166.	2890.	5354.
Tension Coining	1210.	2470.	5180.

cc. Type of Fastener Shank

Several different types of fastener shanks have been developed for use on fatigue life improving fasteners. Conventional straight shank fasteners are by far the most common type and have been used in conjunction with interference fit holes and cold-worked holes to achieve significant life enhancement. Tapered shank fasteners have also been used with

considerable success in fatigue life enhancement. The Taper-Lok fastener provides a means for closely controlling interference through control of fastener protrusion, if the fastener hole has been properly drilled. Lobed fasteners, such as K-Lobes, on which the lobes are parallel to the fastener shank, have been shown to give fatigue life enhancement. Other lobed fasteners including Sine-Loks, the lobes of which are circumferential around the fastener shank, and tapered Sine-Loks, which combine both a tapered shank and circumferential lobes, have been developed.

This series of tests used only straight shank fasteners, although some tapered holes were drilled, some intentionally, others unintentionally.

dd. Fastener Head Type

There are a variety of fastener heads available with numerous variations of both flush (countersink) and protruding heads. Countersink heads on most commercial hardware and wood screws have an 82-degree included angle. Some aerospace use has been made of 60-degree included angle countersinks. Additionally, some work has been done with fasteners having a 70-degree included angle head in a hole drilled with an 82-degree countersink; for example, the Boeing BAC B30PT bolt. The most common flush head style has a 100-degree included angle, but even here there are variations. The tension head configuration is sized as the AN 510 bolt was. Shear head styles have been developed, particularly for use in thinner materials and use reduced head heights.

Similarly, protruding head styles, such as the pan head, filister head, and cheese head, have been used in the past. The pan head has now been chosen for standardization in aerospace fasteners. However, when external wrenching surfaces are required, hexagon head, 12-point, and 12-spline heads are used.

This series of tests used 100-degree included angle flush fasteners with full head height on 240 specimens. The other 240 specimens used protruding pan head fasteners.

ee. Hole Straightness

Holes which are not straight can produce bending moments in the fastener, when it is installed, and a corresponding reaction in the sheet material. These stresses may result in higher peak fatigue loads being induced in the structure and lead to early failure. This hole deviation can result from drill wander as the hole is drilled. Reaming the hole will usually reduce the nonlinearity of the hole. However, in very deep holes it is almost impossible to eliminate. Some drilling techniques, such as the use of point drills and rigid drilling fixtures and tools, tend to reduce the nonlinearity of holes.

No intentionally crooked holes were drilled for this series of tests. Each hole was traversed with an indicating gage and the deviation was recorded.

ff. Fastener Removal

Fatigue critical fasteners are not normally replaced in service. Nevertheless, occasionally fatigue critical joints necessitate the removal of fasteners for joint inspections, structural inspections in areas otherwise not accessible, or for modification or structural repair of the components. When this fastener removal occurs, degradation of the joint fatigue life may result, since fastener removal may damage the structure.

In this program 24 specimens were selected for fastener removal after one half of their estimated fatigue life had been used up in testing. The fasteners were removed, one at a time, and then replaced with the same type fastener and collar. This removal was done while the specimens were in the fatigue test machine. Test machine cycling was stopped, and the load reduced to a previously determined value which was high enough to maintain specimen stability in the machine. After both fasteners had been removed and replaced, the desired test conditions were re-established, and the specimen was cycled to failure. The fastener removal is shown in Figure 12.

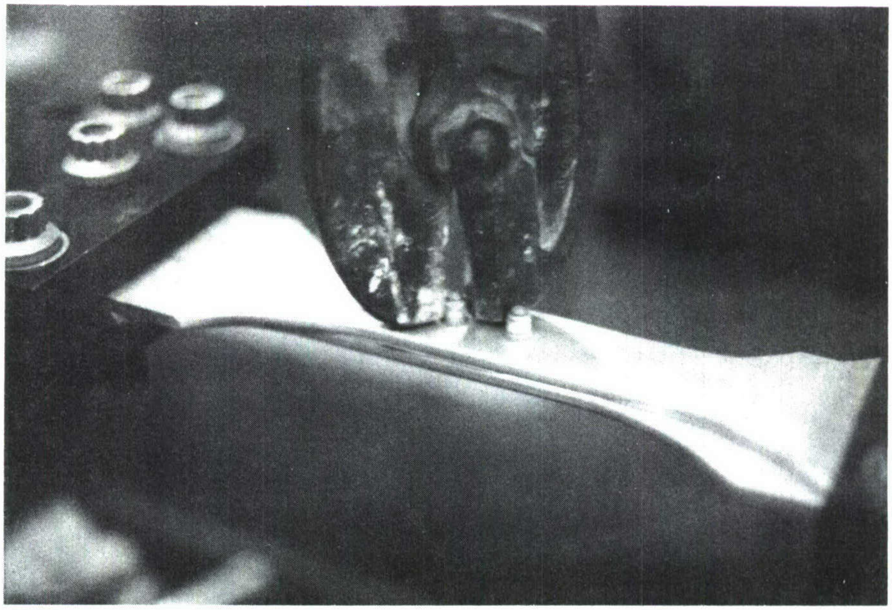

Figure 12. Fastener Removal

When fastener removal was required, the collar was cut off of the bolt, and the bolt was pressed out. An identical fastener and collar were installed, and the other fastener was then removed and reinstalled.

2. EXPERIMENT DESIGN

The experiment was limited by the availability of material and time for its completion. The complexity of the experiment, that is, the number of variables and the number of values each could assume, precluded the use of a factorial design.

After determination of the variable factors was completed, each test condition was assigned to a group of four specimens. The technique employed was based on the use of the predetermined relative frequency of assignment and a pseudo-random number generation technique which involved the use of a multiplicative congruential algorithm (Reference 55). The assignment of a particular feature, for example, head style, to a group of four specimens was based on the calculator generated pseudo-random number. Each variable was assigned to all 120 groups for four specimens, and then the next variable was selected for assignment. The group size of

four was chosen as a compromise between the increased ability to evaluate interactions, which 480 groups of one would have given and the more usual 5 to 15 replications frequently used in fatigue testing. The larger groups lead to greater confidence in the results of that test condition but of course allow fewer different conditions to be tested.

This assignment of test target values for each specimen was then coded, punched, and computer processed. One of the processing steps was an analysis of the experiment design, which is included as Appendix A. Another product was a master list of test target conditions which was used in preparing the specimens for testing.

Inherent in this approach was the data analysis technique. All data was entered into a computer file and then the stepwise regression analysis computer program BMD02R (Reference 56) produced a series of predictive equations.

These experimental design and analysis techniques were chosen because they appeared to offer the most efficient means of extracting useful information on the influence of the large number of variables on the fatigue life of each specimen. Draper and Smith, Daniel and Wood, Lee, and Hicks have all given explanations of the use of regression analysis and have demonstrated the utility of this analysis (Reference 57). The Evolutionary Operation Approach, proposed by Box and Draper, (Reference 58), was considered but not selected, since it did not appear to be as efficient in its use of experimental material, particularly in an experiment where time and material were as constrained as they were in this case.

SECTION III

SPECIMEN PREPARATION AND TESTING

1. SPECIMEN MANUFACTURE

The aluminum used in this program was procured by Rockwell International Corporation and was furnished to the B-1 System Program Office at Wright-Patterson AFB. There were 12 sheets each 36 inches by 144 inches by 1/4 inch from a single heat. The specimen blanks were machined in the shops of Sacramento Air Logistics Center to the dimensions shown in Figure 13. The specimen blanks were then shipped to Wright-Patterson AFB, Ohio. The width and thickness of the center of the test section of the specimens, the region between the two 0.125-inch pilot holes, was measured and recorded. Each specimen blank had been uniquely identified with an engraving tool to provide tracking by specimen blank number.

The specimens which were to have surface treatments or finishes applied were taken by Air Force Materials Laboratory personnel to the Columbus Division of Rockwell International, where the specimens received

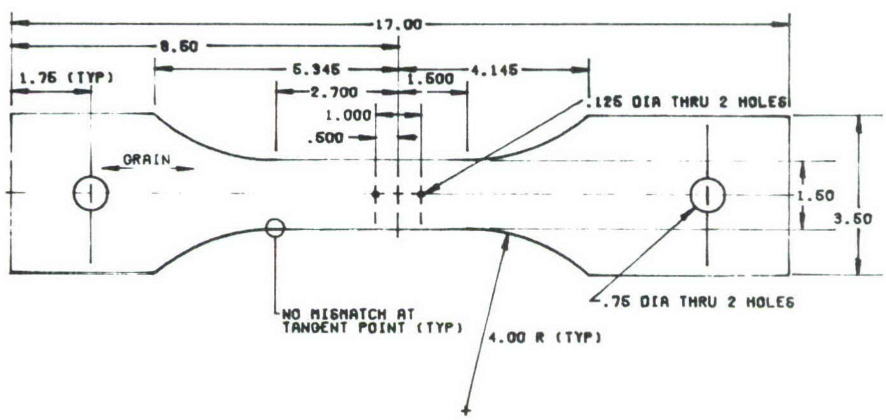

Figure 13. Dimensioned Sketch of Test Specimen Blank Configuration

a chemical conversion coating, and some specimens were primed or primed and given a polyurethane top coat, as described in Section II. These specimens were then returned to Wright-Patterson AFB, where they were assembled, holes drilled to target size, measurements made, and testing accomplished.

If the specimen designs required cut portions of the specimen blanks, as the 50% load transfer and the 100% load transfer specimens did, they were cut by hand using a hacksaw.

2. SPECIMEN ASSEMBLY

The specimens were then assembled. In order to maintain alignment of the specimens and to further ensure that there was no slip between the ends of the specimens, the grip sections of the 5% load transfer and the 50% load transfer specimens were glued together using an epoxy adhesive. Care was taken to ensure that adhesive was placed only in the grips of the specimens. At the same time, if the specimens required a faying surface treatment, such as lubrication, sealing, or adhesive application, such treatment was accomplished. The specimens were then clamped together with a 3/4-inch diameter bolt through each of the 0.75-inch holes in the ends of the specimens and the adhesive was allowed to cure for 24 hours. The clamping bolts were removed, and the specimens were prepared for fastener hole drilling.

3. HOLE AND COUNTERSINK DRILLING

Straight holes were drilled on a South Bend vertical drill press, powered by a one-half horsepower electric motor. Normal drilled holes were drilled using a sharp, clean drill of the same diameter as the previously specified target hole diameter. The drill speed was 740 rpm, and a smooth continuous feed was used. Kerosene was used as a lubricant.

Holes which were to be drilled and reamed were drilled in the same manner, except that the drill bit used was one size smaller than the target hole diameter. The holes were then enlarged to their final diameter in a single cut with a reamer whose size was the same as the target diameter. Reaming was also done at 740 rpm, the slowest speed available on this drill press.

Roughened holes required special preparation of the drill bits. Negative angles were ground on the drill. Then the cutting edges were dulled by rubbing them by hand against a carborundum stone. The drills selected were one size smaller than the target hole diameter. These drills were then forced into the specimens without lubricant at the highest feed rate that could be achieved without stalling the drill press motor. On the occasions where the drill press motor was stalled, the drill was removed from the hole and the motor restarted, and this was continued until the hole was completed. Several of the smaller diameter drills broke, usually as they penetrated the lower surface of the specimen. These drills were pressed out of the hole and drilling was resumed with another similarly prepared drill. The use of an undersized drill in this abusive manner generally resulted in a hole which was close to the target diameter. Nothing was done to smooth out the rough surfaces left by this abusive drilling, and in at least one case, the tool mark from a drill break was identified as a crack initiation site in a failed specimen. Micrographs of this specimen showing the tool mark are located in Appendix D.

The intentional roughening is not meant to simulate the production techniques used in aerospace construction but rather to approximate the worse quality holes which could be produced. These intentionally roughened holes were useful as a laboratory technique for getting information on very bad quality holes.

Holes which were abusively drilled probably simulate more closely the worst quality which could be expected, if there were poor production supervision. Abusively drilled holes were drilled with drill bits which had been intentionally dulled and nicked with a carborundum stone. They were drilled without any lubrication and were forced through the material at a high feed rate. On both roughened and abusively drilled holes, the drill was pulled back out of the hole as soon as the point had fully penetrated the lower surface of the specimen. In many cases this produced a spiral groove (rifling) in the side of the hole. Rifling is recognized by the aerospace industry as a problem with holes prepared in fatigue life critical structure.

During drilling all specimens were securely clamped to the drill press table, and while this clamping undoubtedly reduced the vibration in the specimen, it was necessary for the safety of the machinist performing the operation. Figure 14 shows the hole drilling operation.

Specimens which called for tapered holes were drilled with a hand-held drill. The machinist drilling the holes allowed the drill to move and produced a tapered hole through his movement of the drill bit while the drill was producing the hole.

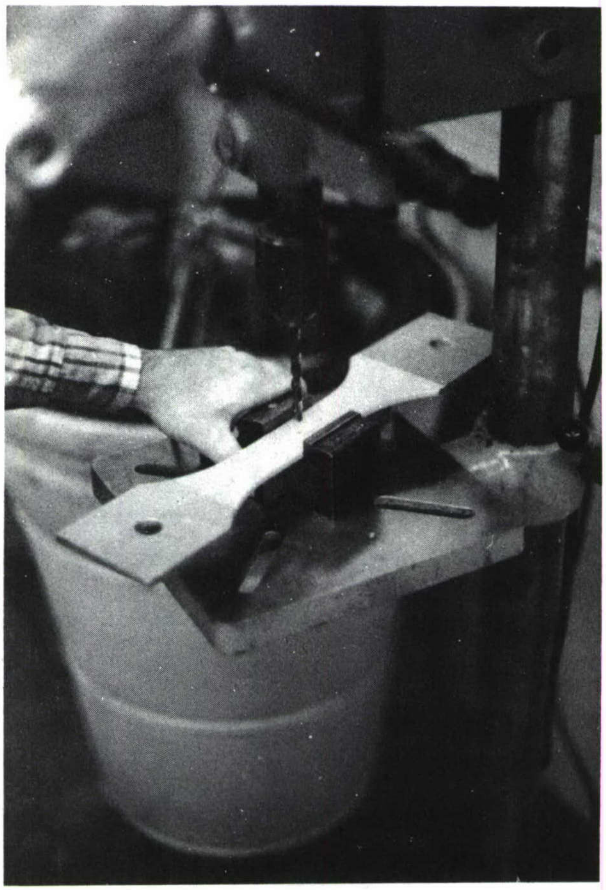

Figure 14. Typical Setup for Drilling a Normal Hole in a Zero Load Transfer Specimen

Because of the depth control, angle control, and offset control required on the countersinks, all countersink operations were performed on a Benchmaster Tool table model milling machine. Cutting was done at approximately 550 rpm with slow feed rates. No lubrication or cooling was used during countersinking. Countersink surface finish was consistently found to be near 32 microinches, although set-up difficulties allowed only a few specimens to be checked.

4. SPECIMEN MEASUREMENT

Following hole drilling and deburring when called for, the hole diameters were measured at both the top and lower surfaces of each hole. On holes with burrs or with visible surface imperfections, the diameters were measured with a Brown and Sharp Inside Micrometer. On smooth holes these diameters were measured with a taper gage.

Hole straightness and minimum edge distance were then measured. The specimens were clamped to a vertical angle plate set on a surface plate. The hole was traversed from top to bottom with an indicator gage, and the deviation recorded. Similarly, the distance from the edge of the sheet to the edge of the hole was measured with an indicator gage, and the minimum measured value was recorded.

Profilometer measurements of the surface roughness were accomplished, measuring along the longitudinal direction in the hole. Circumferential measurements of the surface roughness were not made.

Conformal rubber plug castings of each hole were made, and the castings were allowed to cure in the holes overnight. These castings were identified by specimen sequence number and have been preserved for future research. In addition, approximately 200 specimens were made available to Air Force Materials Laboratory personnel who recorded motorized eddy current scans of the holes. These scans will be used in further research efforts.

5. COLD-WORKING

Specimens which were to receive hole cold-working were then moved to the cold-working area. Appropriate length and diameter sleeves were selected. If wet installation was required, the holes were coated with zinc chromate primer. The cold-working sleeve was placed in the hole, and the selected diameter tapered mandrel was pulled through the hole using a Huck Model 353 Pneumatic Installation Tool. After hole cold-working the hole diameters were measured again and the amount of cold-work computed and recorded.

6. FASTENER INSTALLATION

Those specimens requiring wet installation of the fasteners then had their holes coated with zinc chromate primer, and the appropriate fasteners were installed. Most interference fit fasteners were double driven; that is, pulled into the hole with the installation tool operating at a reduced air pressure. When the fastener was fully seated, the installation tool was removed from the fastener, and the collar was placed on the fastener. The installation tool was then replaced on the fastener and the installation cycle completed. Figures 15 and 16 show fastener installation.

After fastener installation the gap between the sheets was measured with a feeler gage. This measurement was made in between the two fasteners, and the value recorded was the maximum gap in the area between the fasteners.

7. SPECIMEN TESTING

Specimen testing was done on a 20-ton capacity Schenck Fatigue Machine. Prior to each test the dry bulb and wet bulb temperatures were recorded. The recording thermometer was placed approximately ten feet from the test section of the machine. With the wet and dry bulb temperatures, the Psychrometric Tables (Reference 59) yielded the relative humidity. The dry bulb temperature and the relative humidity were recorded.

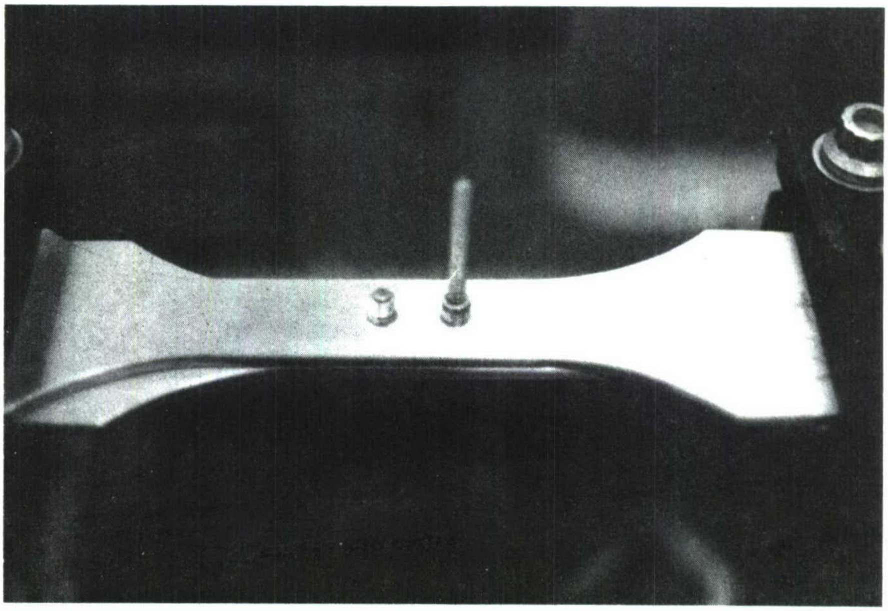

Figure 15. Interference Fit Fasteners Double Driven

Note, the bolt was pulled into the hole, and then the collar was placed on the pin as is shown here.

Figure 16. Technician Using the Pneumatic Installation Tool

Figure 16. This photograph shows the technician using the pneumatic installation tool to pull the fastener into place and install the collar. The specimen shown is a 5% load transfer specimen. This shows reinstalling a fastener after removal. The original installation was similar, except that the specimen was not mounted in the test machine.

The test specimen was placed in the grips of the test machine and a 3/4-inch bolt placed through the grips and the 0.75-inch hole in the end of the test specimen. Approximately 500 pounds preload was then placed on the specimen, and the specimen was leveled as the preload was applied. The preload served to ensure the alignment of the specimen in the test machine. The bolts around the edge of the specimen grip section were then tightened. Figure 17 shows specimen leveling during installation.

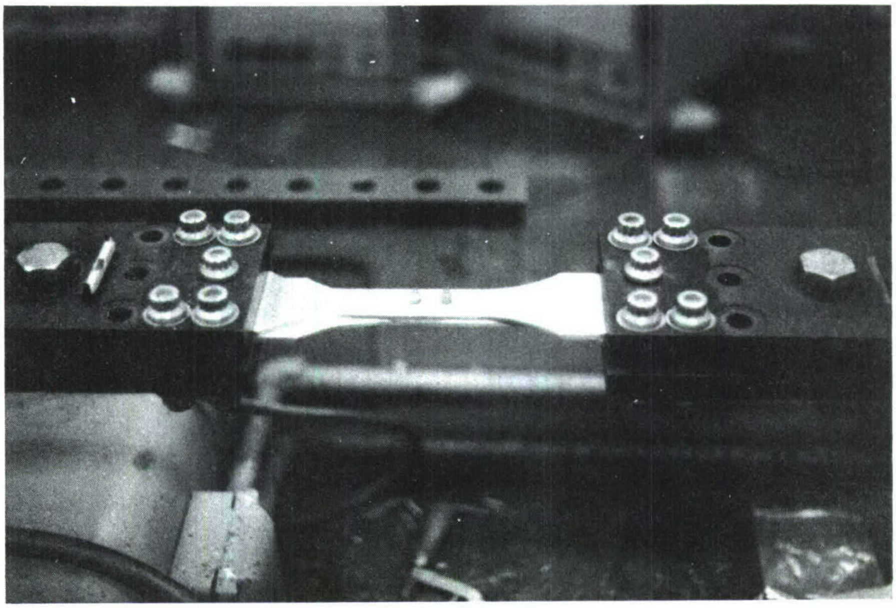

Figure 17. 5% Load Transfer Specimen Shown During Installation

Figure 17. This 5% load transfer specimen is shown during its installation in the fatigue test machine. The bolts on the side of the grips have been tightened and a level is being used to check the horizontal installation of the specimen.

After all bolts had been tightened, the preload on the specimen was increased to the mean load present during the test. The cycle counter was read and recorded, and the test machine turned on. Any minor adjustments in load amplitude necessary to achieve the desired maximum and minimum load were made. The load indications were monitored and adjusted as required during the test. On the few occasions where the load was not maintained, the actual values read were recorded (Figure 18).

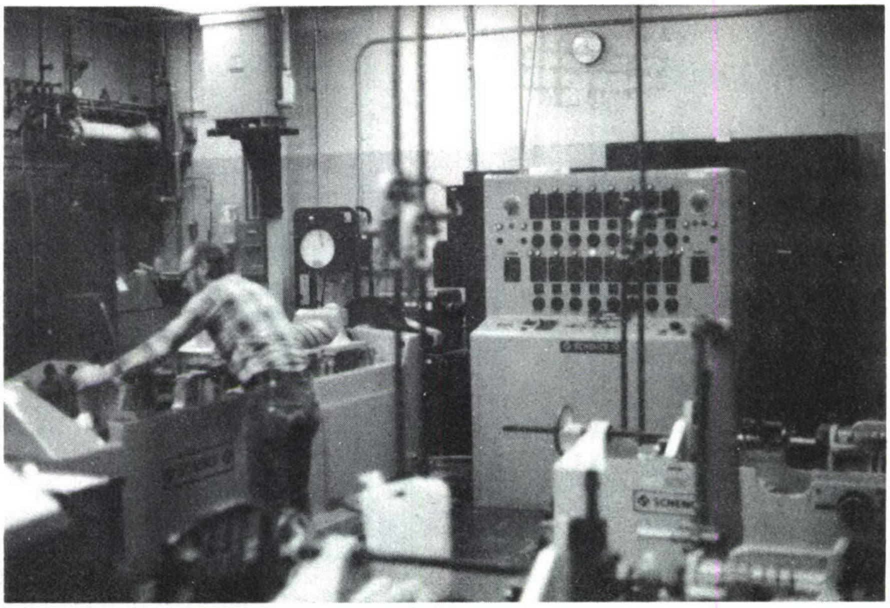

Figure 18. Load Monitoring

The technician is shown making a minor adjustment in the mean load on the specimen during testing.

When the specimen broke, the test machine usually shut itself off. When it did not, the machine was manually turned off, usually within one second after failure. Since the cyclic rate of testing was approximately 20 Hz, and the cycle counter recorded only to the nearest 100 cycles (with interpolation to the nearest 50 cycles possible), any failure of the test machine to shut off automatically was not believed to be significant. After specimen failure the cycle counter was read and recorded, and the test specimen was removed from the grips. The failure surface was examined and the failure code, depending on the failure initiation site, was determined and recorded. A typical failure is shown in Figure 19.

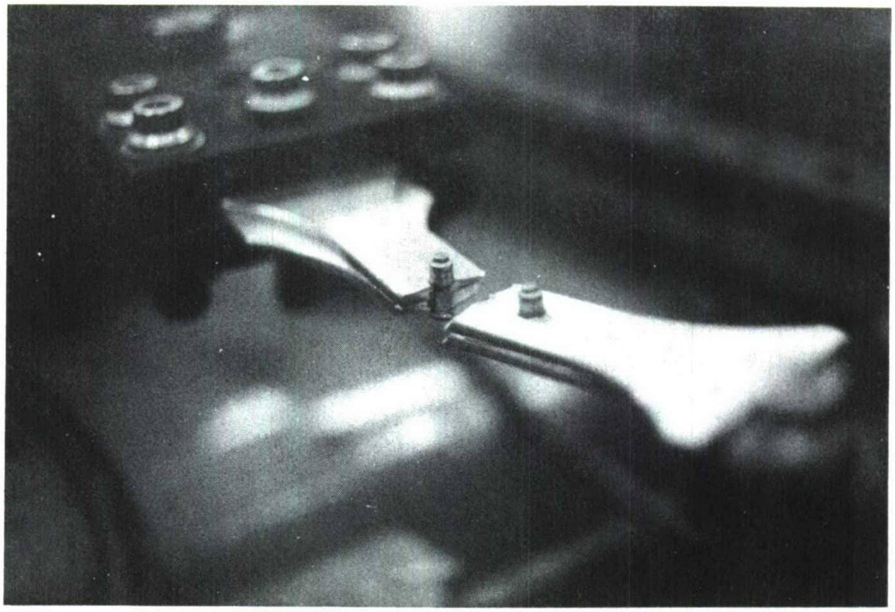

Figure 19. Typical Failure of a 5% Load Transfer Specimen

The fastener had been wet installed, and the head and collar of the fastener have sealed the zinc chromate primer in the hole so well that it has not fully cured. The primer has moved into the fatigue crack that developed along the fastener and can be seen coloring the fracture face next to the fastener.

8. FAILURE CODE

The failure code was a three-digit number identifying the point on the specimen where the crack originated. The first digit of the failure code was the sheet number, with 1 being the sheet immediately under the head of the fastener, 2, the next sheet down, and 3, the next sheet down. Thus, all zero load transfer specimens, having only one sheet, had the first digit of their failure code as 1. Five percent and 50% load transfer specimens could have 1 or 2 as their first digit, and 100% load transfer specimens could have first digits of 1, 2, or 3. In the event that the sheet did not fail, but the fasteners did, the first digit was 0.

The second digit of the failure code was the number of the fastener or fastener hole where the failure originated. This digit was 0, if the failure did not originate at a fastener or fastener hole; for example, if the specimen failed in the grips. A code of 1 indicated that the specimen failed, and a code of 2 indicated the failure originated at the other fastener or hole.

The third digit indicated where relative to the hole the failure initiation point was located. A code of 1 indicated the crack originated at the outer edge of the fastener head, 2 indicated a failure originating under the fastener head or along the side of the countersink, and 3 meant that the crack began at the upper edge of the hole or where the countersink intersected the hole; 4 was the code used to designate a failure which occurred somewhere along the side of the hole. A code of 5 meant that the failure originated at the intersection of the hole and the faying surface; 6 was used to designate a failure in the faying surface but not immediately next to the hole; 7 showed a failure occurring at the collar end of the hole where the hole ends; 8 indicated a failure under the collar; 9 signified that the failure occurred at the outer edge of the collar. Code 0 was used for any failure originating at some other point on the sheet. These failure codes in numerical order are shown in Figure 20.

9. FRACTOGRAPHY

At the end of testing, representative failures were selected for fractography. Both optical and electron microscopy were used in examining these failures. Representative samples of the work done are shown in Appendix D.

10. DATA COLLECTION

The experiment was designed with computer data analysis capabilities as a primary consideration. A directly addressable data file was established. This file was planned so that up to 120 ten-character words could be recorded describing each specimen. A data collection sheet was prepared for each specimen. As each measurement was made,

Failure Code Third Digit

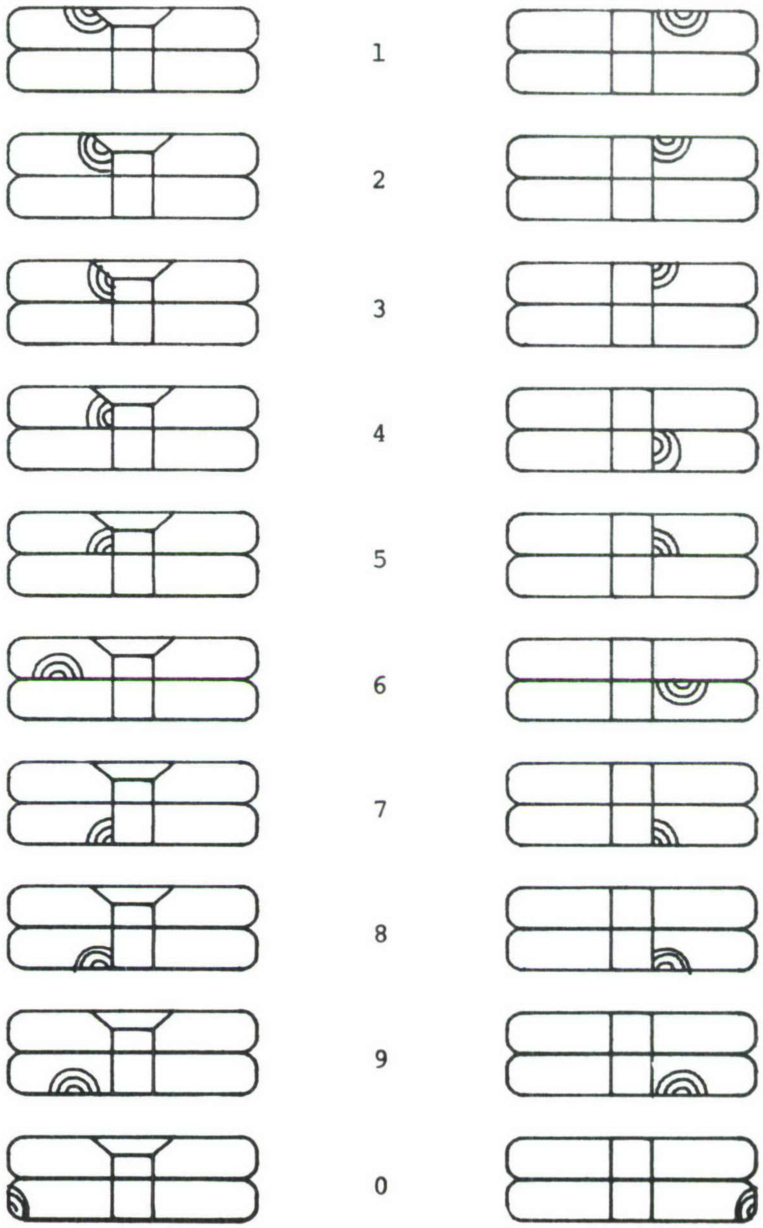

Figure 20. Sketches Showing Failure Code Selection

the data were recorded on the sheet. Periodically, the data were either transcribed for keypunching or were entered directly through an interactive computer terminal. A summary of significant variable values for each specimen appears in Appendix C.

After data entry the file was periodically checked, and random comparisons were made between the original hand-recorded information and the information in the computer. Any errors found were corrected. Furthermore, to catch certain errors where the data could have been significantly out of range, limit values were established for many parameters, and the appropriate file elements were compared against these limits. For example, the sheet thickness, file elements 8, 9, and 10, had to be between .22 inches and .26 inches, if it existed. If any sequence number was found to have these data elements outside these limits, it was identified, and the erroneous information was corrected. Thus, extensive error checking was done, and occasional correction was required. This error checking and data correction continued through the preliminary data analysis, and some of the graphical representations of the data were very useful in identifying the last two or three erroneous entries that were found.

SECTION IV

EXPERIMENT RESULTS AND ANALYSIS

1. FAILURE RELEVANCY

In analyzing the results of an experiment such as this one, where the object of the testing program is to determine the factors which cause or prevent fatigue failures of mechanical joints, one question which must be resolved is: "Which failures are relevant?"

There were 428 specimens out of the total of 480 which failed in the sheet material at or very near a fastener hole. These failures are obviously pertinent to the problem. Twenty-three specimens, all of them 100% load transfer specimens with 3/16-inch fasteners installed, experienced fastener failures. These specimens did not fail in the sheet material, yet the failures they experienced were clearly related to the fatigue life of the joint. Therefore, these must also be classified as relevant failures and included in the data base for analysis.

In a sense the remaining 29 specimens represent the success story of the experiment. The failures which they experienced were not at the fastener hole, although seven of them, all 100% load transfer specimens, had failures which began in the faying surface near a fastener but did not break through the fastener hole. These seven certainly had their fatigue life strongly influenced by the presence of the fastener. The remaining 22 cases showed that the area around the fastener is not the critical area of the specimen. The fastener had been installed in such a way that some other portion of the specimen became the life limiting portion of the specimen. Thus, these specimens should also be included in the assembled data for analysis for their success helps to reveal the factors leading to longer joint life.

Perhaps an even more relevant question would be: "What constitutes an irrelevant failure?" In answering this query, it would be well to refer to the experience of Dantowitz, Hirschberger, and Pravidlo, (Reference 60) who have developed an argument that essentially all laboratory failures are relevant and have counterparts in field service

failures. Consequently, it would seem that failures should be disregarded only if some radical outside influence has directly caused the failure.

2. DATA ANALYSIS

The information on each test specimen contained in the directly addressable computer file was reorganized into a number of sequential files which were used for regression analysis. After approximately 150 regression runs, using a number of different variables, variable transformations, and variable combinations, the following 15 models have been selected for presentation. They were obtained by processing the same variables in different manners and reveal several noteworthy aspects of the joint design problem.

In order to understand clearly the information presented, the output from the BMD02R computer program will be briefly discussed. The result of a regression analysis is a regression equation of the form

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \varepsilon$$

where y is the dependent variable, x_i, the independent variables; the β_0 is a constant, the β_i values are coefficients; and ε represents the error or the amount that any individual y may fall off the regression line. The β_i terms- constant and coefficients, are determined to minimize the ε term. After several possible models were checked, y was found to be predicted best when it was the logarithm to the base 10 of the cycles to failure. The computer program BMD02R allows the user to specify a minimum F statistic which each coefficient must reach before it is brought into the regression equation. The program also allows the user to specify another minimum F statistic which the coefficient must possess, if it is to remain in the regression equation. Consultation with several experienced statisticians at Wright-Patterson AFB established these statistics at $F \geq 2.0$ for a β_i coefficient to enter the regression equation and $F \geq 1.0$ for a β_i coefficient to remain in the regression equation. As a result of setting the F statistics at these relatively high levels, only the more significant variables were used in developing the regression equation for each of the models chosen.

3. MODELS

The models chosen are listed below, and each is briefly discussed. The coefficients (β values) for each model are shown in Table 2.

a. All Cases Combined

This model is perhaps the most general. It uses all 480 cases for input data. While the r^2 value indicates that it is explaining approximately 57% of the variation in specimen lives, other more specialized models for various subgroups of specimens better explain the variation in the fatigue lives of their groups, and this represents a worst case estimation tool for computing fatigue lives. It is notable that only 18 of the 24 possible variables enter this equation.

b. Zero Load Transfer Specimens Only

This model predicts the life of the 80 zero load transfer specimens and explains 86% of their life variability with the use of ten variables out of a possible 24. The relative simplicity of the zero load transfer specimen helps to explain the relative simplicity of the model developed.

c. Five Percent Load Transfer Specimens Only

The 5% load transfer specimen model is considerably more complex than the zero load transfer model. This is a mathematical recognition of the real increase in the complexity of the specimen. This model also shows a decrease in the explanatory power it has in this more complex situation, since it only explains 68% of the specimen life variability. Fifteen variables are used in this equation.

d. Fifty Percent Load Transfer Specimens Only

The 50% load transfer specimen model is one of the least capable of explaining specimen life of any of the models developed, with only 50% of the specimen life variability explained by the model. A closer look into why this model is less useful in predicting specimen life is appropriate. The test specimen it represents has been used

TABLE 2

REGRESSION EQUATION MODELS

Co-efficients	Variable Description	All Specimens
β_0	Constant	6.16
β_1	Gross stress parameter ksi	- .045
β_2	Fastener preload	.0000429
β_3	% load transfer	- .00420
β_4	Countersink misalignment	
β_5	Faying surface coating thickness	14.2
β_6	Hole roughness	.000320
β_7	Hole angle	- .0477
β_8	Countersink angle	.0618
β_9	Hole taper angle	
β_{10}	Hole straightness deviation	
β_{11}	Cold-work	16.7
β_{12}	Edge distance/diameter	.102
β_{13}	Fastener interference	35.2
β_{14}	Fastener removal	.177
β_{15}	% shank contact	.00184
β_{16}	Countersink depth ratio	- .447
β_{17}	Gap between sheets	
β_{18}	Test relative humidity	- .00891
β_{19}	Hole straightness difference	- 9.44
β_{20}	Thickness/diameter	- .221
β_{21}	Fastener wet installed	- .0379
β_{22}	Hole deburred	.102
β_{23}	Coining collar	
	"F" statistic	34.6
	Degrees of freedom	18/461
	r^2	.5749

TABLE 2 (CONTINUED)

Co-efficients	Zero Load Transfer	5% Load Transfer	50% Load Transfer	100% Load Transfer
β_0	6.36	7.29	3.57	4.39
β_1	.0660	- .141	.0432	
β_2	.0000429	.0000575		.00012
β_3		.0938		
β_4			1.79	
β_5		1.29		-64.1
β_6	- .0144		- .000502	
β_7	- .0888			
β_8				.034
β_9		.0727		- .0832
β_{10}				13.5
β_{11}	43.3	17.1		
β_{12}		.893		
β_{13}	95.7	22.2	-41.5	20.6
β_{14}		.106	- .188	
β_{15}		.00211		.00208
β_{16}	- 1.08	- .551		
β_{17}				
β_{18}	.00581		- .00948	
β_{19}			-10.4	
β_{20}		- 1.06		- .164
β_{21}		- .107		- .0842
β_{22}	- .0833	.13		.0574
β_{23}	.152	- .062		
F	43.0	26.9	10.6	21.7
df	10/69	15/184	7/72	10/109
r^2	.8618	.6870	.5063	.6653

TABLE 2 (CONTINUED)

Co-efficients	Average 4 at a Time	3/16-inch Fasteners	1/4-inch Fasteners	5/16-inch Fasteners
β_0	3.88	5.34	3.97	6.79
β_1				- .0725
β_2	.000113		- .0000504	.000058
β_3	- .117	- .00732	- .00292	
β_4	3.93	3.22		
β_5				-25.6
β_6	- .000587		.00104	- .000525
β_7	- .0946		- .109	
β_8				.0575
β_9				
β_{10}			14.4	
β_{11}	43.6	30.4		
β_{12}			.326	
β_{13}	90.8	36.4	26.9	20.6
β_{14}	.275	.116		
β_{15}			.00298	.000908
β_{16}	- .676	- .498	- .317	- .367
β_{17}				
β_{18}		- .0102		
β_{19}				-19.7
β_{20}	.399	- .152	- .315	- .16
β_{21}	.0649	- .114		
β_{22}	.0517		.0438	.136
β_{23}		- .0508		
F	32.9	34.5	61.5	12.0
df	12/107	10/149	11/148	11/148
r^2	.7866	.7038	.8164	.4715

TABLE 2 (CONTINUED)

Co-efficients	Fasteners in Interference	Clearance Fasteners	Cold-Work	No Cold-Work
β_0	6.10	5.70	6.43	6.03
β_1	- .0609	- .036	- .0544	- .0451
β_2	.0000955	.0000528	.0000301	.0000537
β_3	- .0044	- .00275	- .0021	- .00419
β_4				
β_5	-14.6	-30.6	-18.9	-25.8
β_6				.00046
β_7			- .0404	- .0416
β_8	- .0845	.126	.115	.0347
β_9		- .052	- .19	
β_{10}	- 6.57			
β_{11}	33.2	27.3	25.0	
β_{12}	.2	.0738	.363	
β_{13}	74.6			40.8
β_{14}		.816		
β_{15}		.00916		.00216
β_{16}	- .246	- .432	- .433	- .33
β_{17}				
β_{18}		- .00642	- .0118	
β_{19}	-14.8			-20.7
β_{20}	- .271	- .171	- .432	- .143
β_{21}		- .0316	- .0474	
β_{22}		.0903	.0955	.0869
β_{23}	- .0674			- .05
F	32.2	29.9	21.3	33.2
df	13/138	15/312	14/146	14/304
r^2	.7523	.5896	.6717	.6048

TABLE 2 (CONCLUDED)

Co-efficient	0% and 5% Specimens	50% and 100% Specimens
β_0	6.26	4.74
β_1	- .0535	
β_2		.0000618
β_3	- .0455	
β_4		
β_5		-22.2
β_6		
β_7	- .0488	
β_8		
β_9	.0391	- .0643
β_{10}		5.43
β_{11}	20.3	
β_{12}		
β_{13}	39.0	18.55
β_{14}		
β_{15}	.00175	
β_{16}	- .556	.188
β_{17}		
β_{18}		- .00647
β_{19}	- 9.53	
β_{20}		- .161
β_{21}	- .0436	- .0496
β_{22}	.073	.067
β_{23}	- .034	.0359
F	40.9	19.3
df	12/267	11/188
r^2	.6477	.5300

by several investigators, and while Lindh (Reference 61) obtained usable results from this specimen, he also installed strain gages on each specimen to determine the actual load transfer and noted considerable variation in load transfer in his results. This variation in load transfer, as might be expected, related principally to the clearance present between the fastener and the hole. This specimen design also violates the guidance which is typically given aircraft designers by corporate design manuals (Reference 62): to use symmetrical joints!

During testing of the no preload fastener specimens, the asymetrical loading present in the joint manifested itself in fastener pull-out and sheet separation. These specimens had no collars installed on the fasteners, and after approximately 1000 cycles of testing, a gap of about 0.2 inches developed between the two sheets as the fasteners backed out of the lower sheet. The fasteners did not completely pull out of the sheets. However, even with several thousandths of an inch interference, the back-out was noted. Urzi considered this type of specimen in some of the early work that he did in developing standard test specimens for inclusion in MIL-STD-1312 Fastener Test Methods (Reference 63) but found that this configuration did not have the sensitivity to fastener-related variables that other configurations had. Therefore, in fairness to the mathematical model, its inability to resolve the factors determining the variation in fatigue life of this specimen has been previously observed, and this specimen design is no longer in general use for fastener testing.

e. One Hundred Percent Load Transfer Specimens Only

The model for 100% load transfer specimens predicts approximately 66% of the variability in the specimen fatigue life. Like the 50% load transfer specimen, this specimen is unbalanced in the sense that the middle sheet will always be the sheet to fail, if a sheet does fail. However, this is a symmetrical specimen, and the imbalance could be cured by using a center sheet, or sheets, which would have to be as thick as the sum of the thicknesses of the outside sheets. This specimen design was the only one to have fasteners fail. Approximately one half

of the 3/16-inch diameter fasteners failed during the testing. Typically, the fasteners which failed were the fasteners which had relatively low preloads or were in interference, and the preload applied by the installation tool was used to pull the fastener through the sheet material rather than to clamp the sheets together. As a result of the low clamping force between the sheets, the load was transferred through the fastener rather than being split and part of the load being transferred by friction between the two sheets. Nonetheless, the model does a credible job in predicting the fatigue life of the joint.

f. Three-Sixteenths-Inch Fasteners Only

The model for 3/16-inch fasteners using a sample of 160 specimens is able to explain 70% of the variation in the fatigue life of these specimens. This subset of specimens showed the greatest sensitivity to joint gap. This sensitivity may be related to the relatively low clamp-up that these fasteners could impart to the specimens making more of the load transfer through the fastener. With a gap in the joint, the fastener would be experiencing more bending, giving even higher local loads on the material next to the fastener and producing earlier failure.

g. One-Fourth-Inch Fasteners Only

The model for 1/4-inch fastener specimens does the best job of explaining the variation in fatigue life of any of the models which are based on fastener size. While the specimen blanks for this series of experiments were sized originally for use with 1/4-inch diameter fasteners, the ability of the model to explain 81% of the variation in fatigue life cannot be attributed solely to that.

h. Five-Sixteenths-Inch Fasteners Only

This model displays the poorest explanatory ability of any of the models, explaining only 47% of the life variability. Regrettably, this writer is unable to provide a reason for the poor performance of this model.

i. Interference Fit Fasteners Only

The model for interference fit fasteners is relatively good; that is, it explains 75% of the variation in fatigue life for the 154 interference fit fastener specimens. This model shows that interference is about twice as effective in increasing fatigue life as cold-work.

j. Fasteners Not in Interference

This model explains about 59% of the variation in specimen life. It is noteworthy that even in this model the hole surface roughness is not a factor in the life prediction equation. One knowledgeable nondestructive inspection researcher predicted that this model would show the greatest sensitivity to surface roughness.

k. Cold-Worked Specimens

The model for cold-worked specimens provides explanation of 67% of the specimen life variability. In this equation the fastener interference does not influence specimen life. This is contrary to Lindh's findings (Reference 64) which claimed that some interference enhanced the effects of cold-work.

l. Specimens Without Cold-Work

This model is almost as powerful in explaining the variations in fatigue life as the model for holes with cold-work. It explains 60% of the variation in specimen fatigue life.

m. Zero Percent and 5% Load Transfer Specimens Combined

This model was suggested on the basis that there should be some significant similarities between the zero and 5% load transfer specimens. Unfortunately, the combined model does not explain the variation in fatigue life as well as either of the individual models do, explaining only 64% of the variation.

n. Fifty Percent and 100% Load Transfer Specimens Combined

Like the previous model, this model seeks to use the elements common to the two higher load transfer models. However, here the model's explanatory effectiveness, 53%, is in between the effectiveness of the other two models.

o. Specimens Averaged Four at a Time

Since the experiment was set up with four replications of each test condition, this model averaged the parameters, including specimen life, for each group of four specimens. This averaging resulted in a loss of individual specimen differences, including life differences, within the group of four, and therefore, even though the model explained 78% of the variation in average results, it is not considered a very useful model.

4. INDIVIDUAL FACTORS

In order for the models to be accepted, the individual parameters must be meaningful to those working in the area. In many cases the parameters can be shown to correspond with other data, thus making the model more easily understood.

a. Gross Area Stress Parameter

The gross area stress parameter is

$$\sigma_{max} \cdot \sqrt{1-r} \text{ ksi}$$

and in the all-cases model has a β_1 parameter of -.055. This means an increase of 1. ksi in the gross stress parameter causes the predicted life ($\log_{10}$ cycles to failure) to decrease by 0.055.

Extensive S-N data on 2219-T581 has been generated in connection with the design of a new aircraft (Reference 65). For the region of interest for this problem we find the data summarized in Table 3, which shows that the model's computed value for the change of 1. ksi in the gross stress parameter is close to the average values developed from other fatigue testing. This is reassuring in that it indicates that the model's performance in computing the role of gross area stress in determining fatigue life is comparable with the results of the extensive materials characterization program which was undertaken in quantifying the properties of this alloy.

TABLE 3

SLOPE OF THE S-N CURVE FOR 2219-T851 WITH K_t BETWEEN 1. AND 12.

K_t	1.	2.	3.2	5.	12.
Cycles to Failure					
33 ksi	4.0×10^6	4.0×10^4	6.5×10^3	5.9×10^3	1.6×10^3
28 ksi	1.5×10^7	1.1×10^5	1.4×10^4	1.2×10^4	3.5×10^3
Log_{10} Cycles to Failure					
33 ksi	6.61	4.60	3.81	3.77	3.20
28 ksi	7.18	5.04	4.15	4.08	3.54
Difference	- .57	- .44	- .33	- .31	- .34
Difference/5	- .11	- .888	- .067	- .063	- .068

Similarly, the 50% probability of survival curve for a gross area stress of 30.7 ksi (r = .1) as a function of K_t has been plotted from the same data source (Reference 66), and it is shown in Figure 21. Similar plots could be constructed for any stress parameter level, and they would allow the determination of the initial equivalent K_t, given the fatigue life of a specimen. Plots showing the effect of gross stress on specimen life are shown in Figures 22 through 33.

b. Preload

Fastener preload in pounds seems to have a weak effect on specimen lives. The effect was most noticed in testing two groups of high load transfer specimens which had deep countersinks. The specimens had relatively long lives (near 100,000 cycles), and the failures did not occur at the fastener holes, but rather from cracks in the faying surface about 0.1 inches from the holes. The high preload had forced the load to transfer through friction to a greater extent than it had in other cases, and the fatigue life of these specimens was longer than most other 100% load transfer specimens. The importance of preload seems to increase as the load transfer increases, as can be observed in Figures 34 through 45.

c. Load Transfer

Load transfer, entered in percent, consistently served to decrease the fatigue life of the specimens. Of course, as the load transfer increases the loads on the fasteners increase, and thus the loads on the material next to the fastener are increased leading to earlier failures.

d. Countersink Misalignment

Countersink misalignment, measured in inches, up to the limits used in this series of tests and with the countersinks offset in the direction perpendicular to the loading direction, did not have a significant influence on fatigue life. If this conclusion could be confirmed by other testing, it would argue that factors other than fatigue life enhancement require countersink alignment with the fastener hole, and if these other requirements would allow for loosening tolerances, cost savings might be realized.

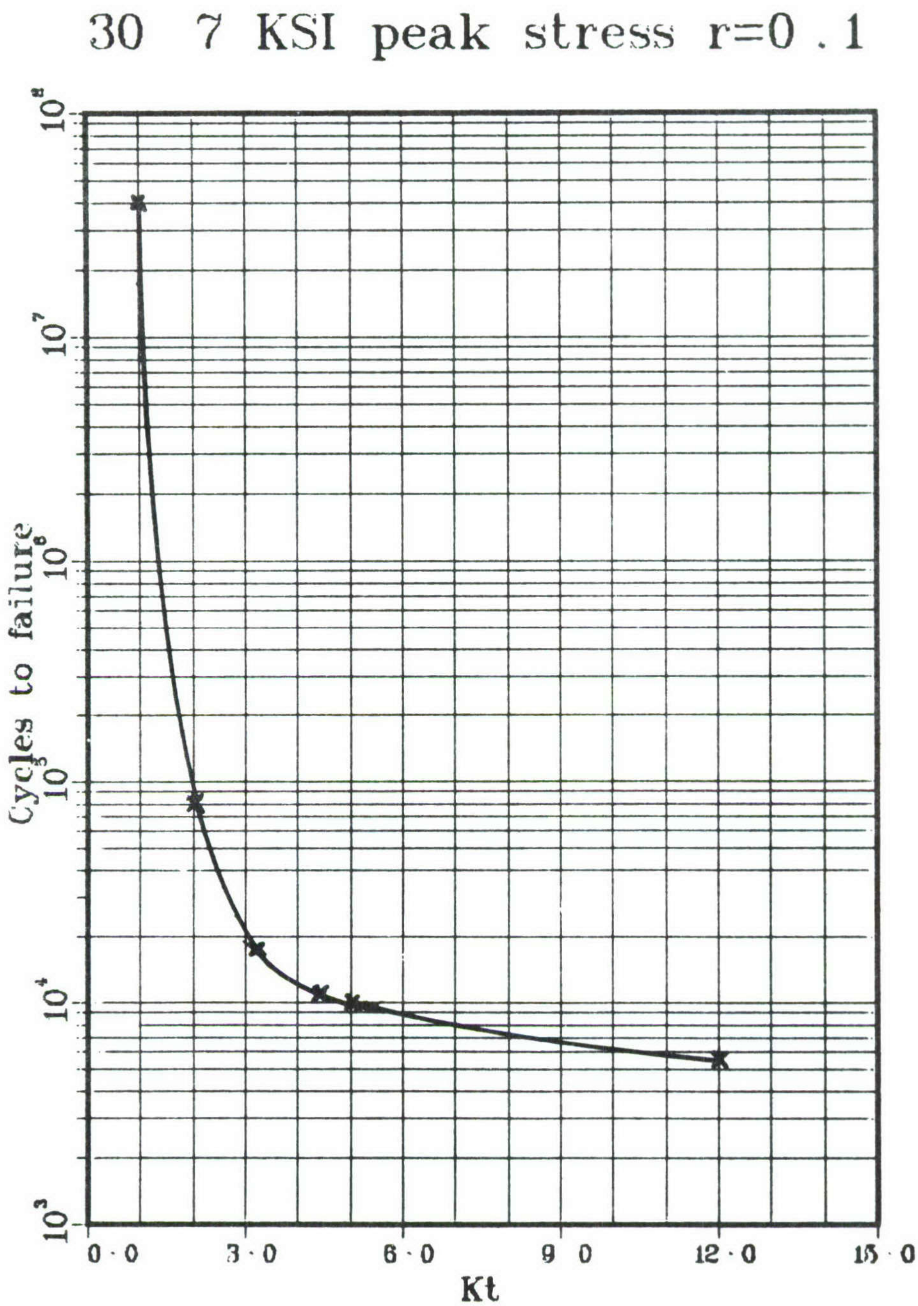

Figure 21. K_t vs. Cycles to Failure

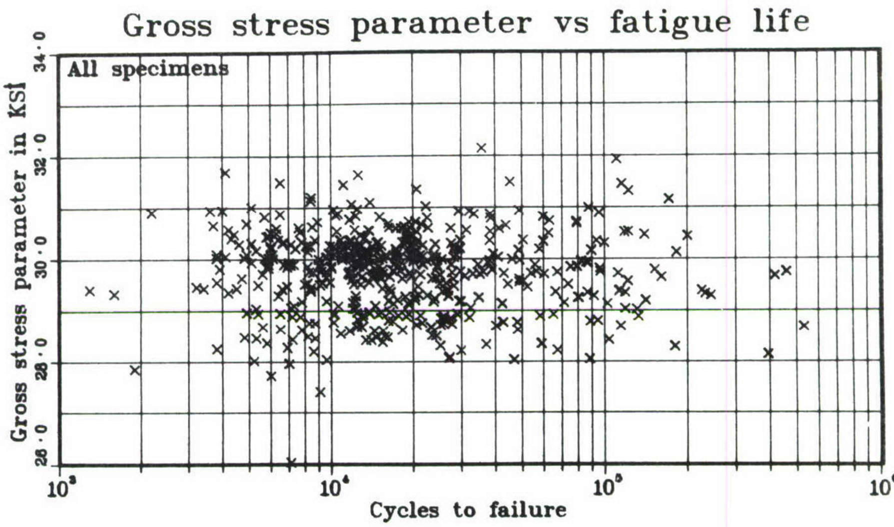

Figure 22. Gross Stress Parameter vs. Fatigue Life for All Specimens

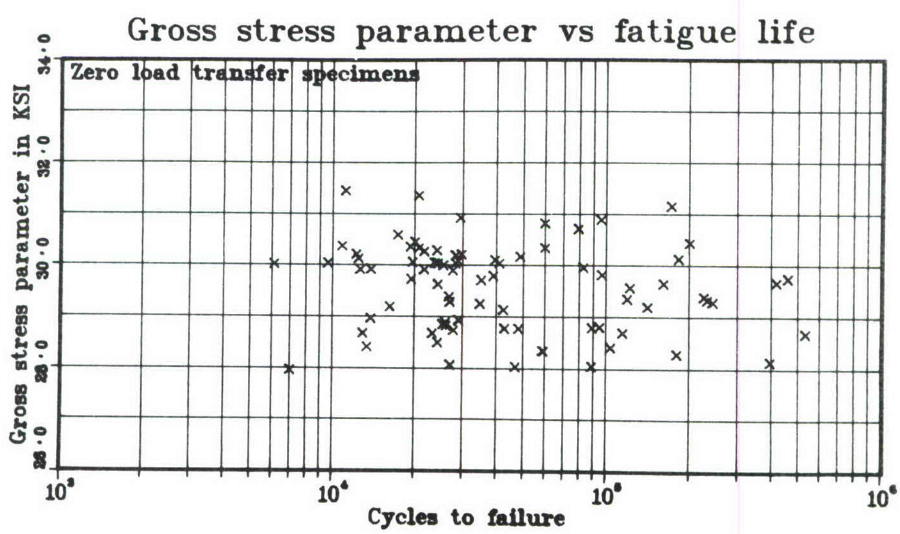

Figure 23. Gross Stress Parameter vs. Fatigue Life for Zero Load Transfer Specimens

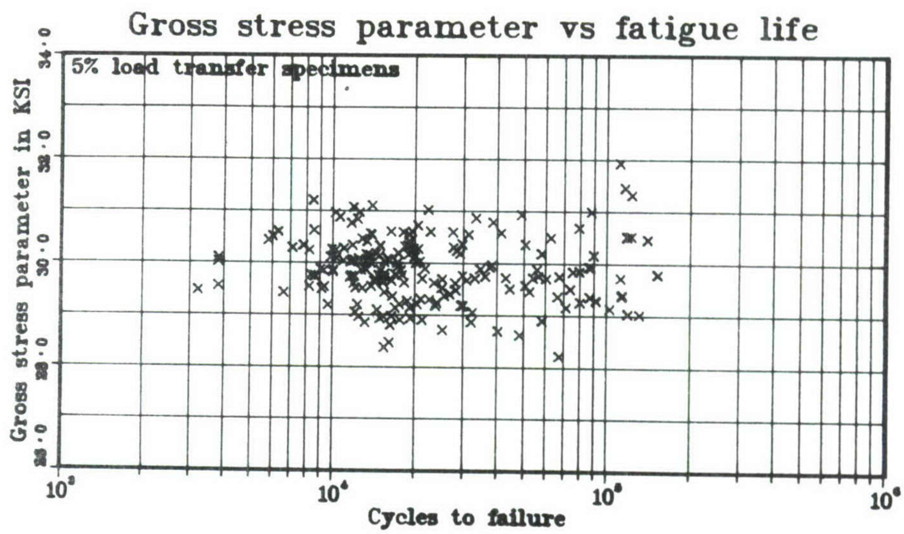

Figure 24. Gross Stress Parameter vs. Fatigue Life for 5% Load Transfer Specimens

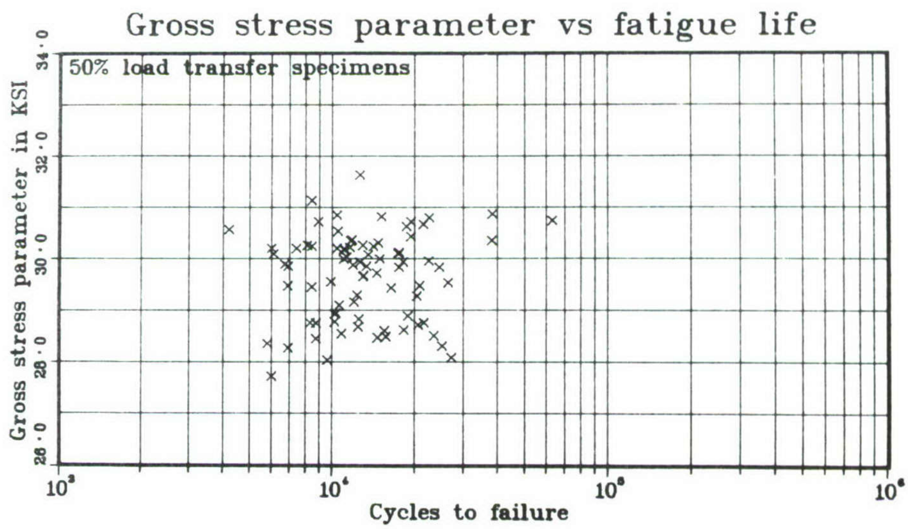

Figure 25. Gross Stress Parameter vs. Fatigue Life for 50% Load Transfer Specimens

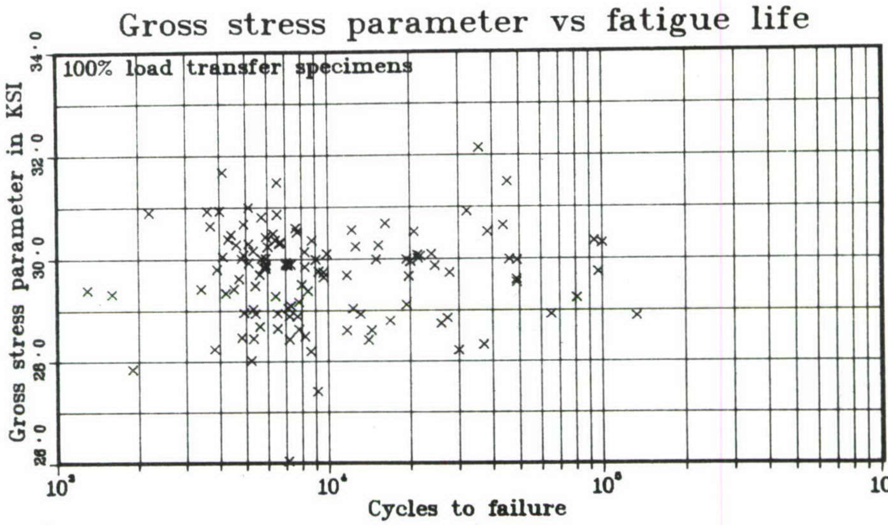

Figure 26. Gross Stress Parameter vs. Fatigue Life for 100% Load Transfer Specimens

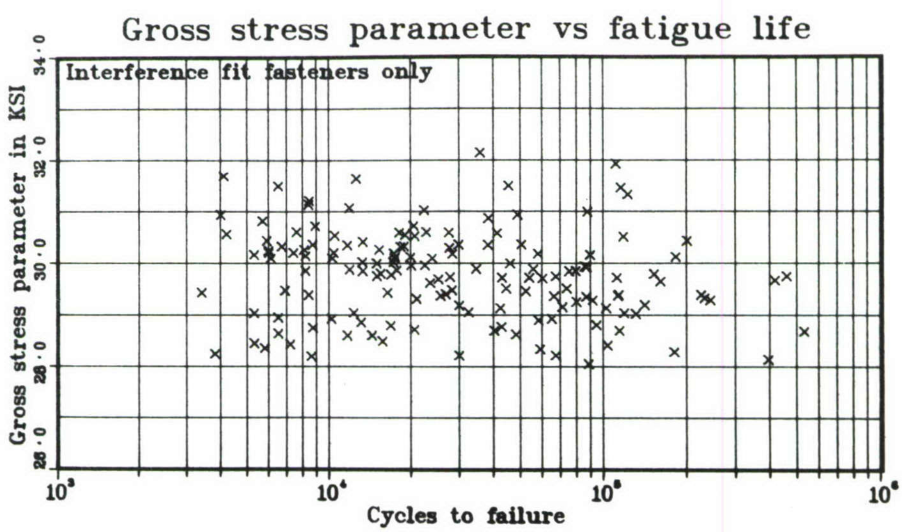

Figure 27. Gross Stress Parameter vs. Fatigue Life for Interference Fit Fasteners Only

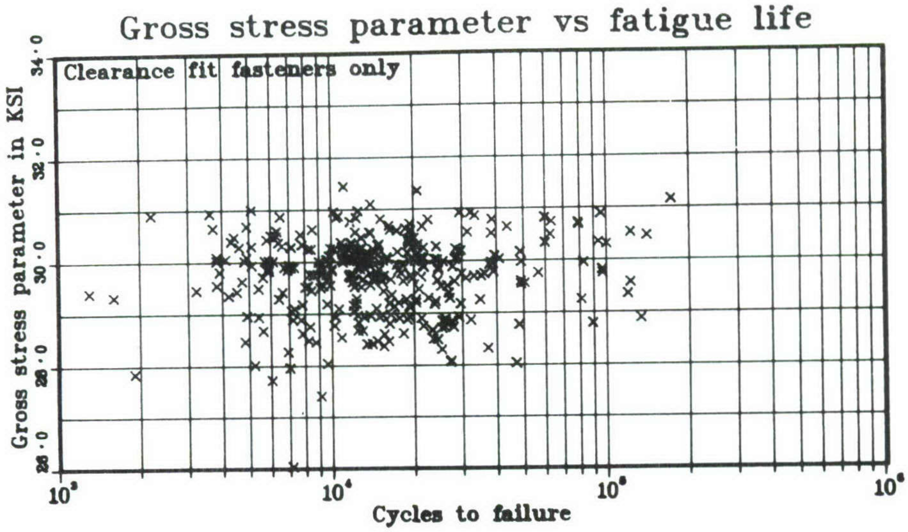

Figure 28. Gross Stress Parameter vs. Fatigue Life for Clearance Fit Fasteners Only

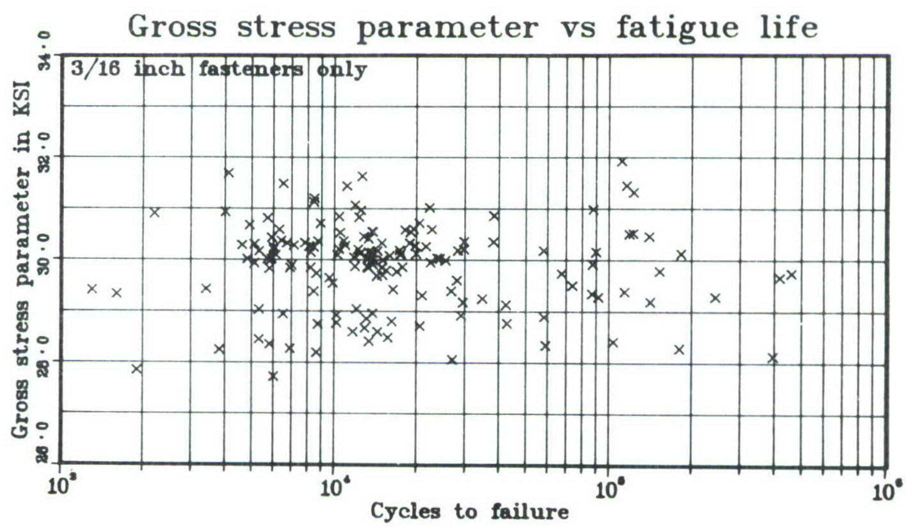

Figure 29. Gross Stress Parameter vs. Fatigue Life for 3/16-Inch Fasteners Only

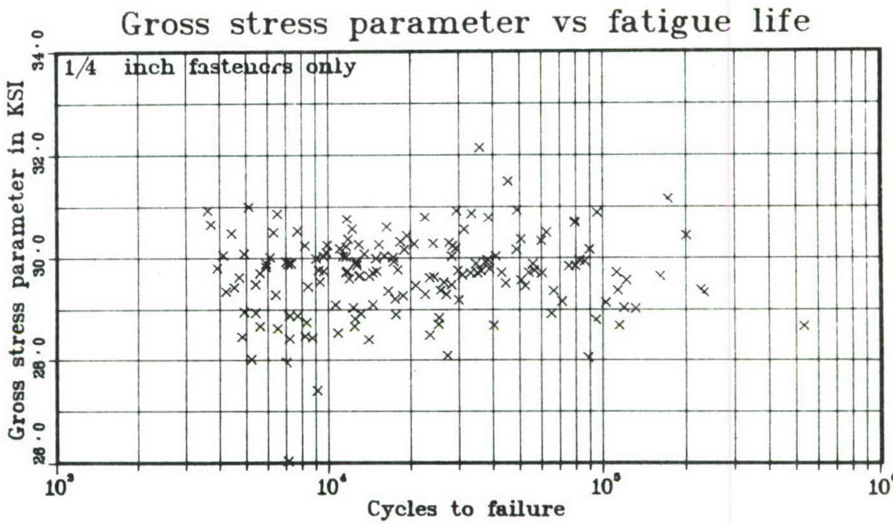

Figure 30. Gross Stress Parameter vs. Fatigue Life for 1/4-Inch Fasteners Only

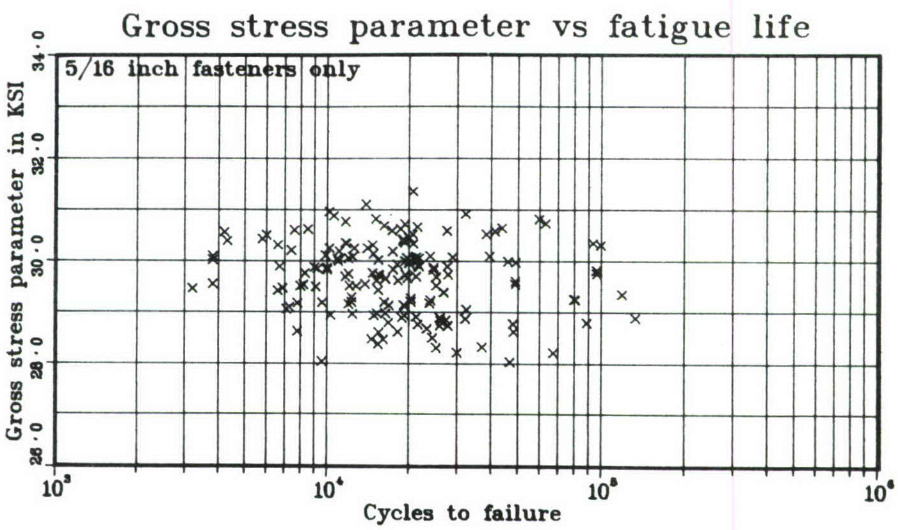

Figure 31. Gross Stress Parameter vs. Fatigue Life for 5/16-Inch Fasteners Only

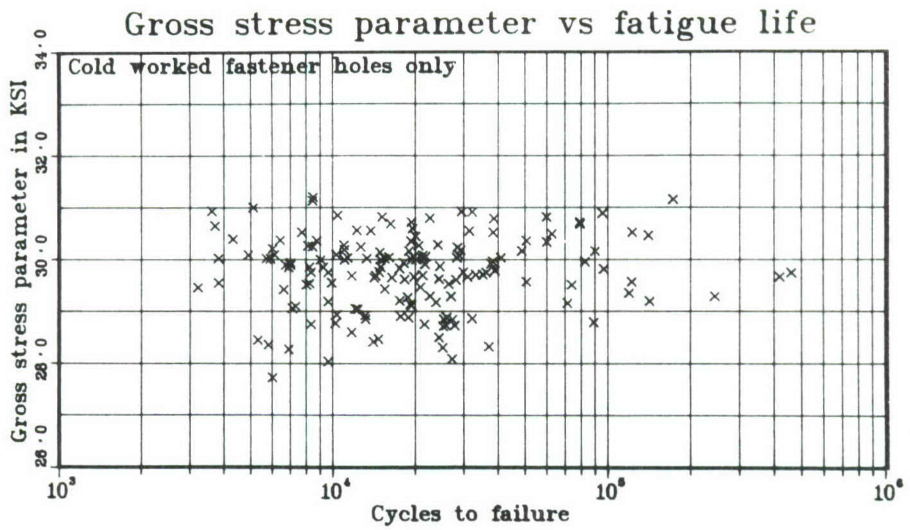

Figure 32. Gross Stress Parameter vs. Fatigue Life for Cold-Worked Fastener Holes Only

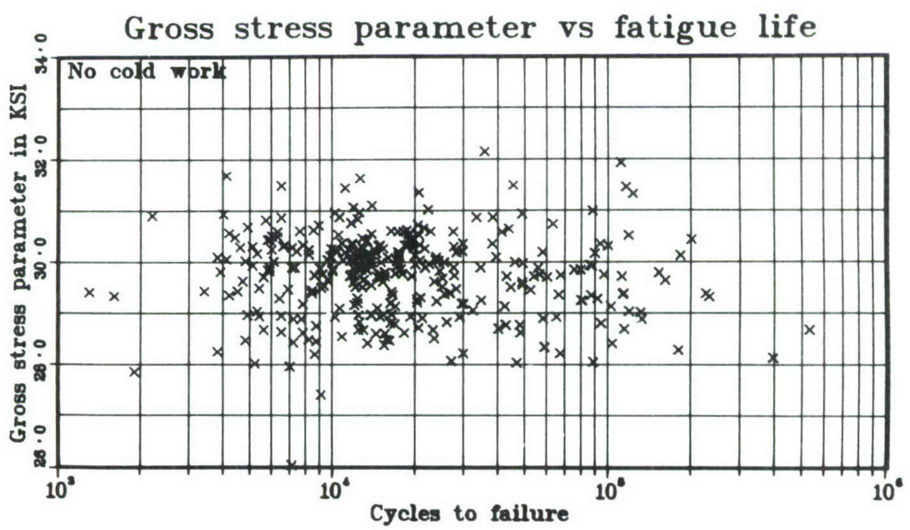

Figure 33. Gross Stress Parameter vs. Fatigue Life for No Cold-Work

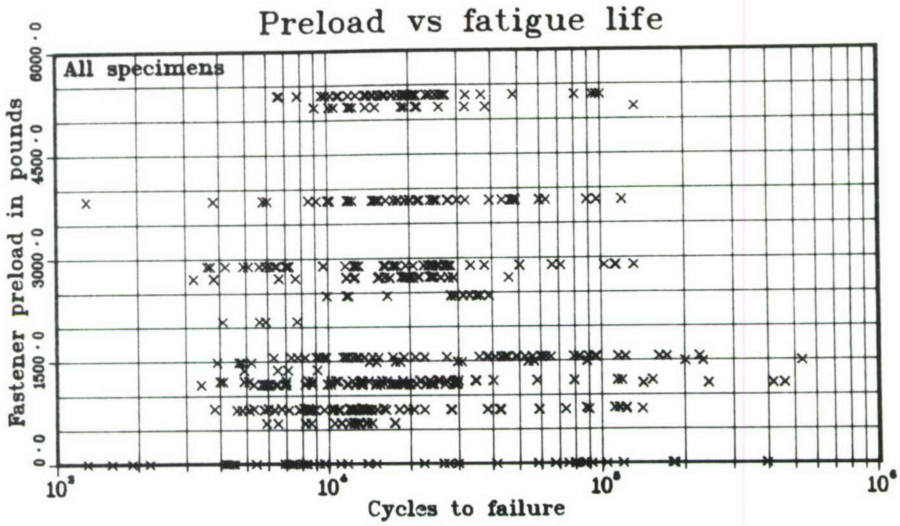

Figure 34. Preload vs. Fatigue Life for All Specimens

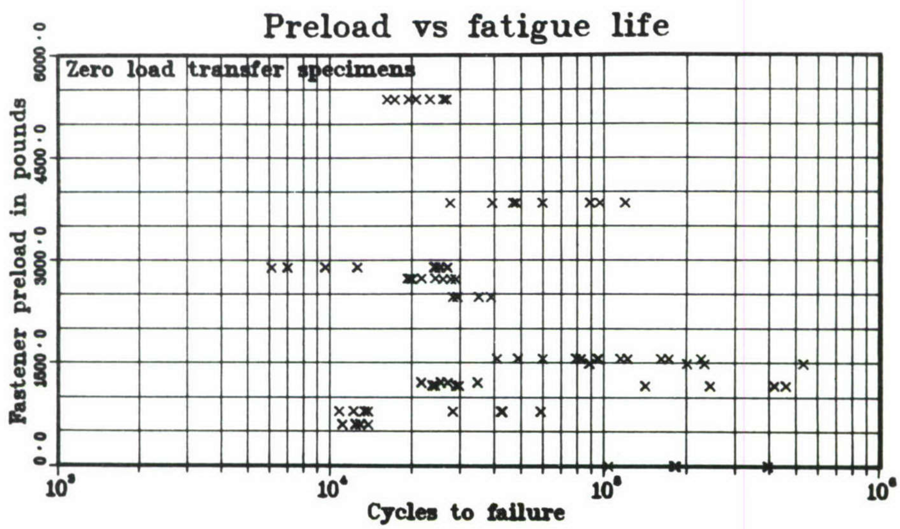

Figure 35. Preload vs. Fatigue Life for Zero Load Transfer Specimens

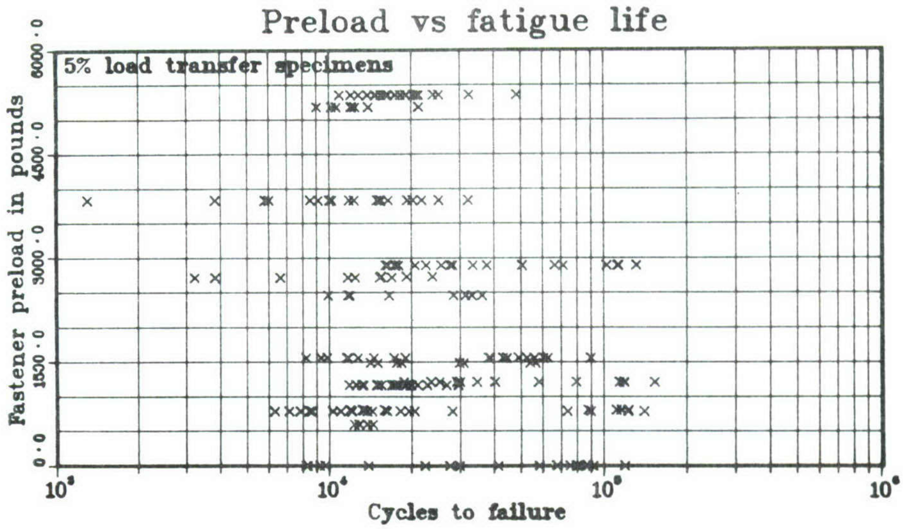

Figure 36. Preload vs. Fatigue Life for 5% Load Transfer Specimens

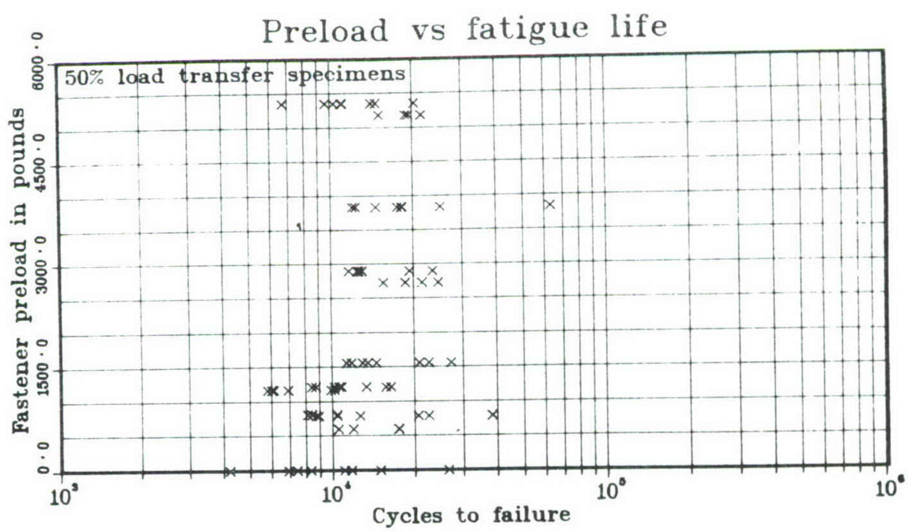

Figure 37. Preload vs. Fatigue Life for 50% Load Transfer Specimens

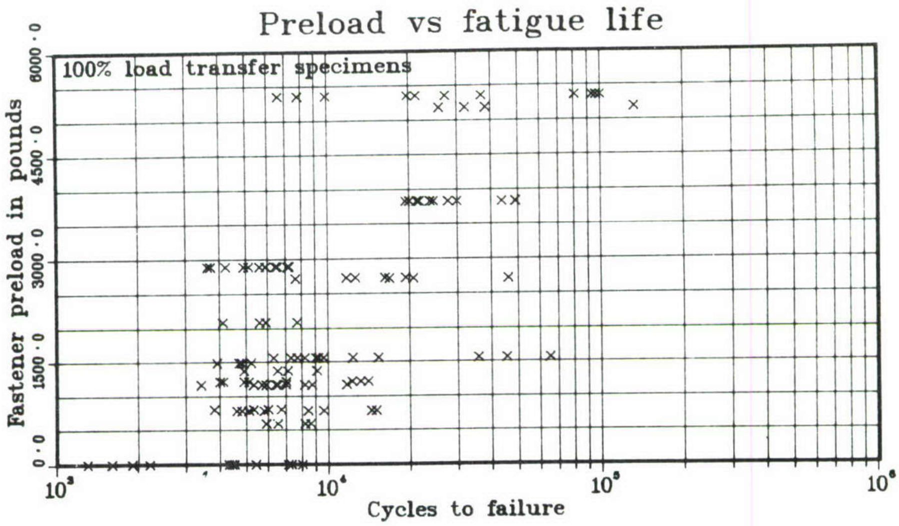

Figure 38. Preload vs. Fatigue Life for 100% Load Transfer Specimens

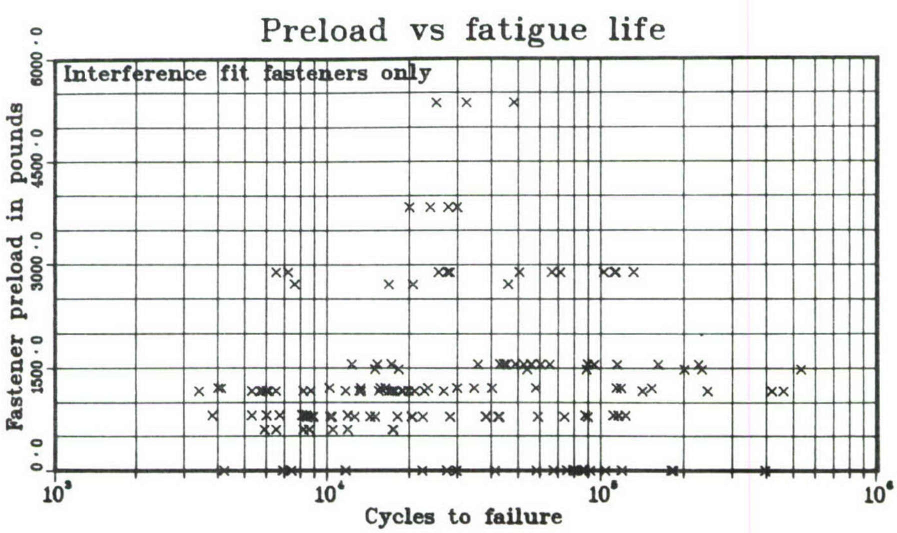

Figure 39. Preload vs. Fatigue Life for Interference Fit Fasteners Only

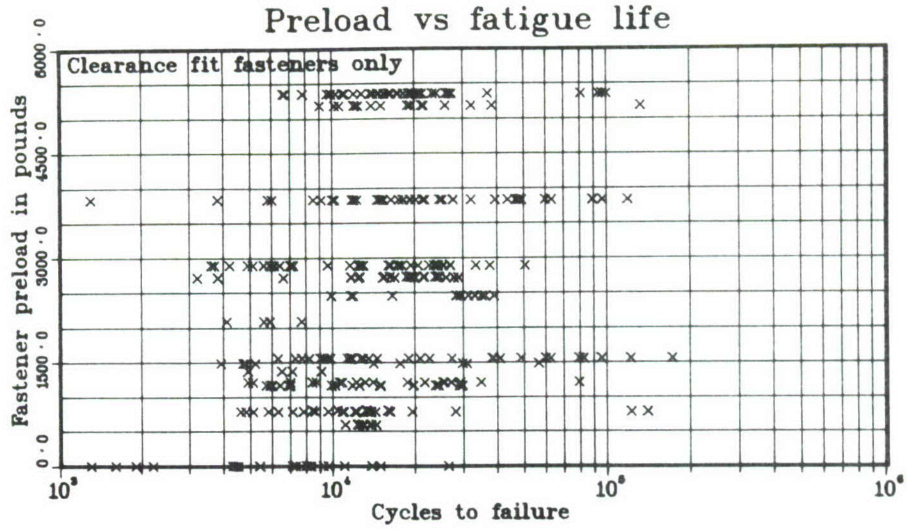

Figure 40. Preload vs. Fatigue Life for Clearance Fit Fasteners Only

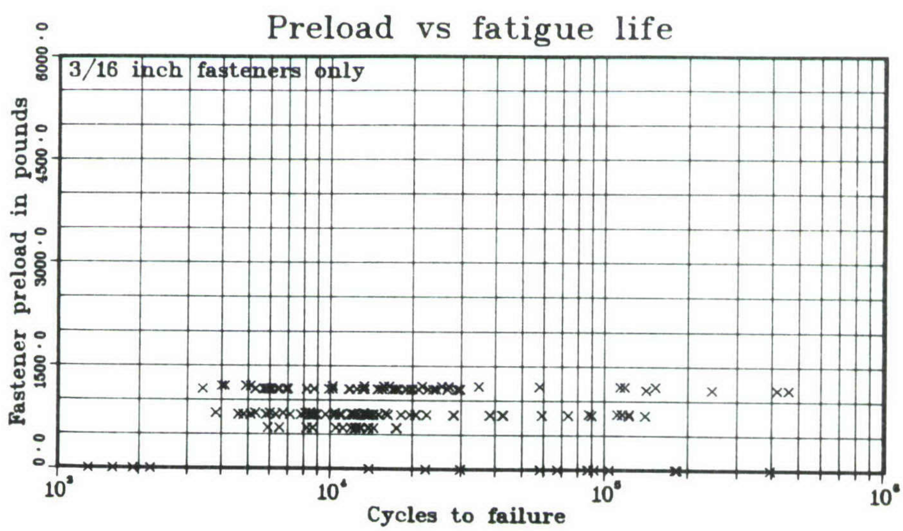

Figure 41. Preload vs. Fatigue Life for 3/16-Inch Fasteners Only

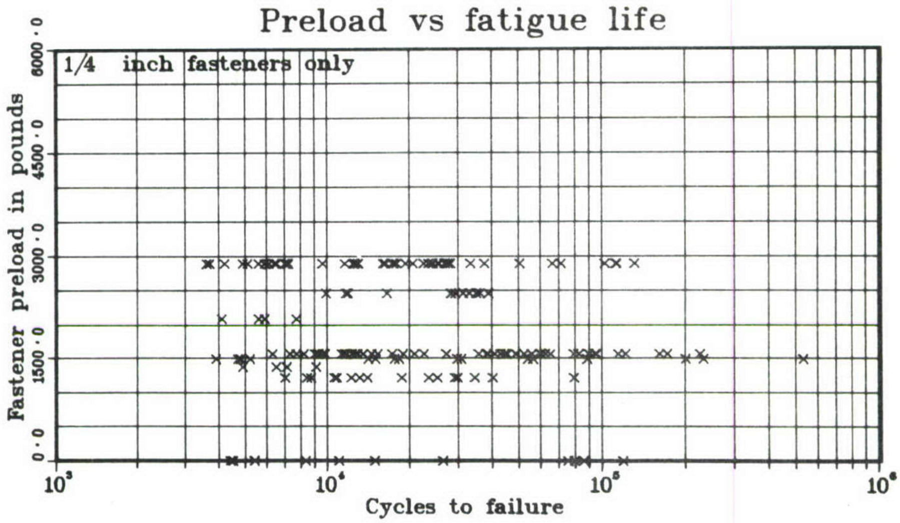

Figure 42. Preload vs. Fatigue Life for 1/4-Inch Fasteners Only

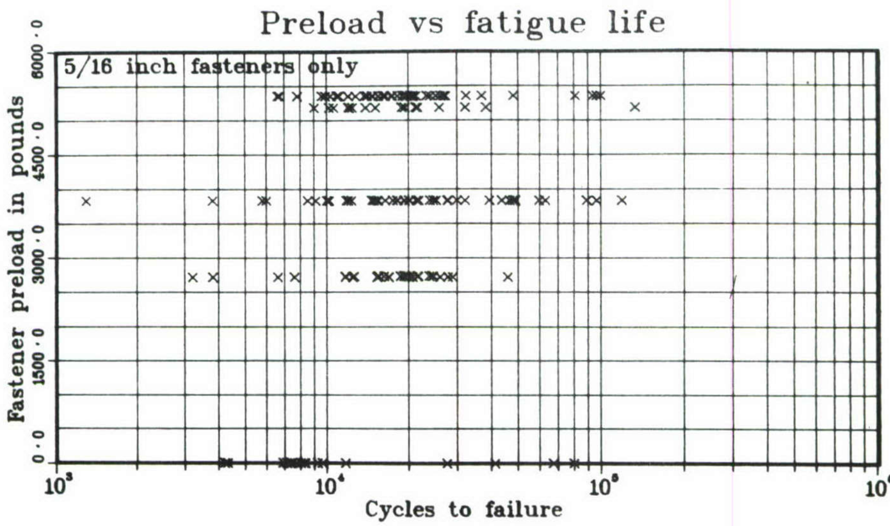

Figure 43. Preload vs. Fatigue Life for 5/16-Inch Fasteners Only

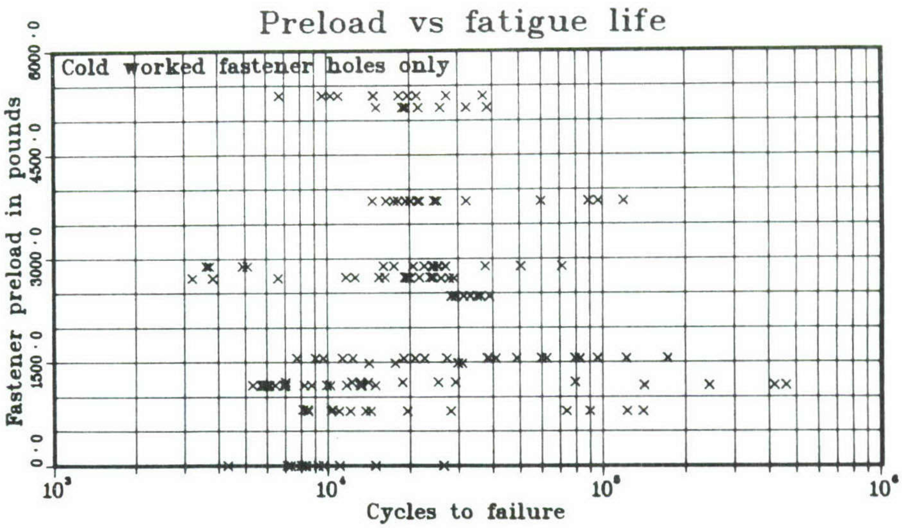

Figure 44. Preload vs. Fatigue Life for Cold-Worked Fastener Holes Only

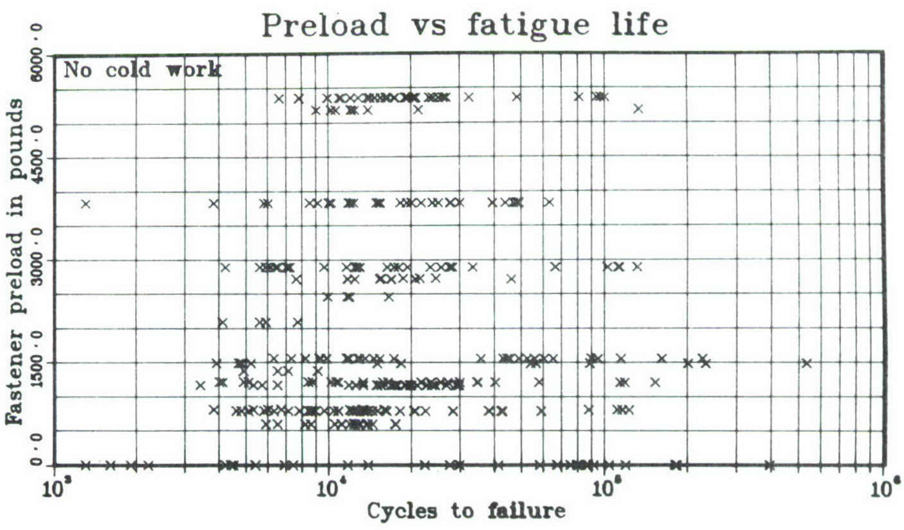

Figure 45. Preload vs. Fatigue Life for No Cold-Work

e. Faying Surface Coating Thickness

While there was some decrease in life with increased thickness, neither the thickness measured in inches, nor the type material in the faying surface significantly influenced fatigue life in most models. This was initially surprising, particularly considering the considerable evidence that adhesives, properly applied, significantly increased fatigue life. However, on re-examining the faying surfaces of some of the adhesively bonded specimens, it became apparent that a good bond had not been achieved in most cases. This failure, which was tentatively attributed to improper adhesive choice and inadequate surface preparation (no prebond etching), indicated that the experimental technique was improper and that there was no reason to question the efficacy of properly applied adhesives as a fatigue life enhancement technique.

The weak effect of increases in faying surface coating thickness on fatigue life probably relates more to the reduction in friction which results from increased thickness than from other factors. The effects are shown in Figures 46 through 56.

f. Hole Surface Roughness

The effect of hole surface roughness, measured in microinches, on specimen fatigue life was one of the real surprises provided by the models. While some materials, such as D6AC steel, seem to require considerable attention to the surface finish of the fastener holes, the testing done here on 2219-T581 aluminum in this program indicates that it is almost completely insensitive to hole surface roughness. This result should not have been so surprising for in informal conversation with fastener experts on the subject of hole roughness, occasional comments were made that perhaps too much attention had been given to surface roughness and that the effort expended there could well be placed in other areas. The results of this testing would support a view of this sort, particularly for this material and at stress levels similar to those used for this program.

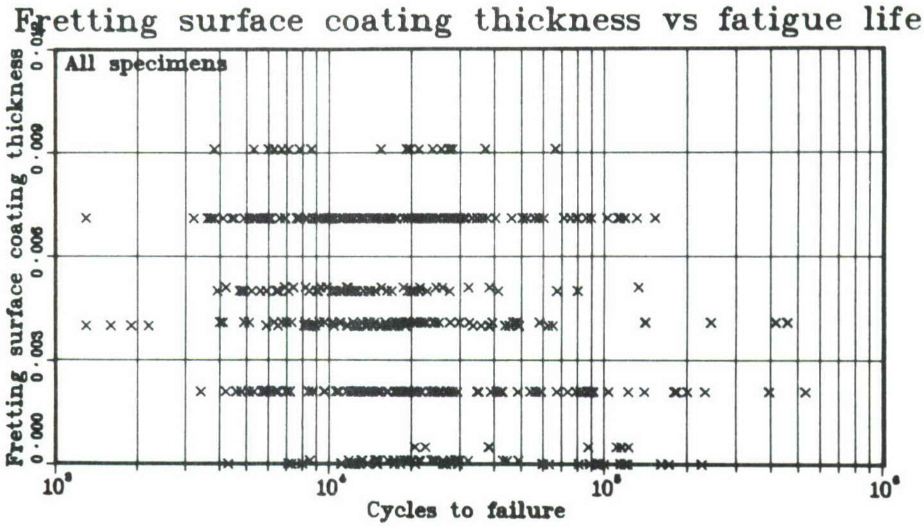

Figure 46. Fretting Surface Coating Thickness vs. Fatigue Life for All Specimens

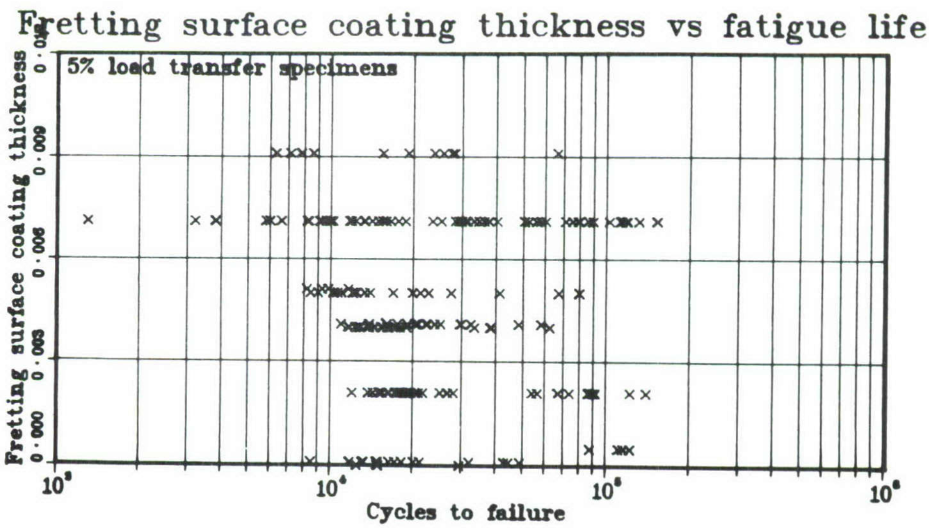

Figure 47. Fretting Surface Coating Thickness vs. Fatigue Life for 5% Load Transfer Specimens

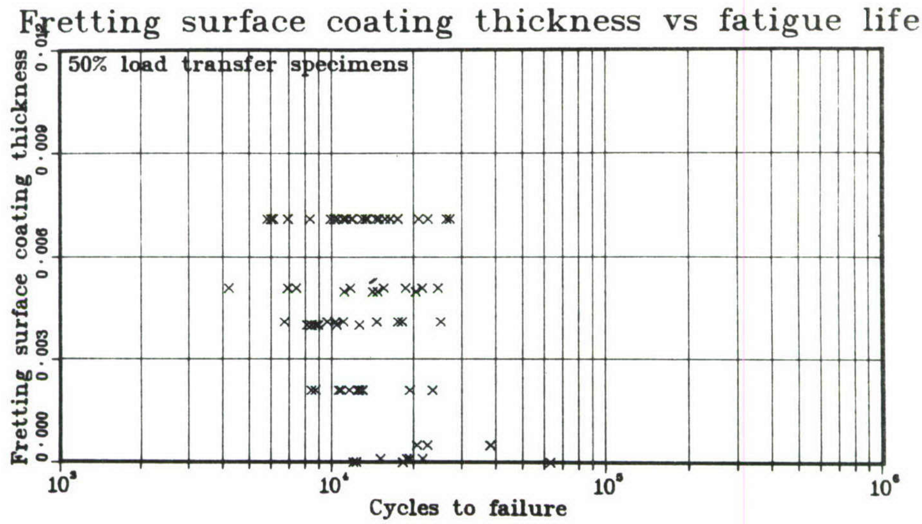

Figure 48. Fretting Surface Coating Thickness vs. Fatigue Life for 50% Load Transfer Specimens

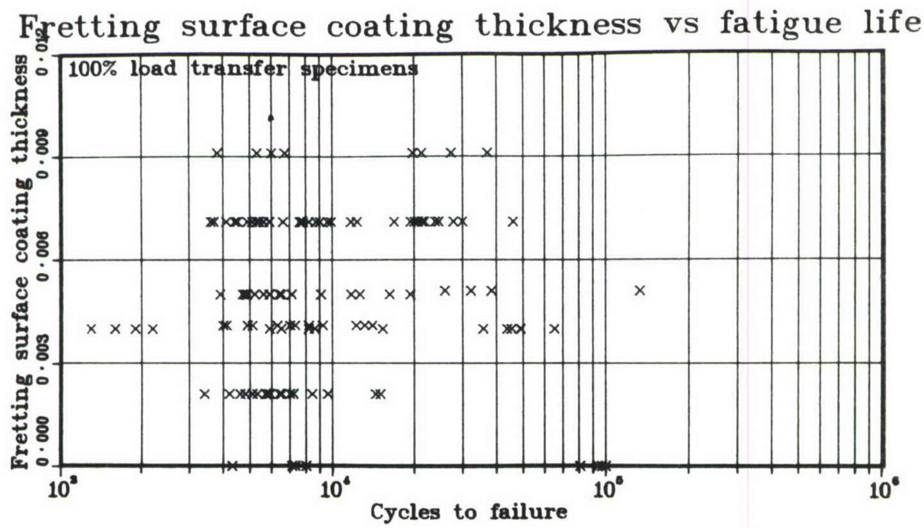

Figure 49. Fretting Surface Coating Thickness vs. Fatigue Life for 100% Load Transfer Specimens

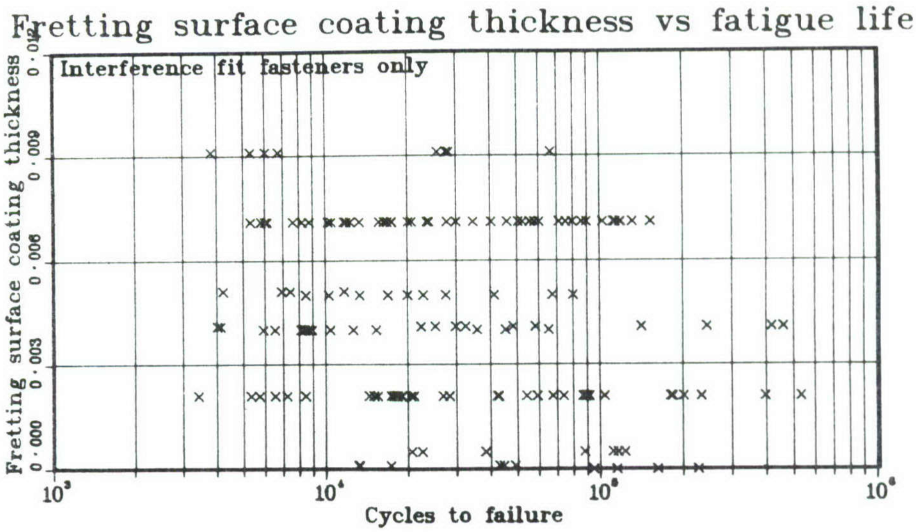

Figure 50. Fretting Surface Coating Thickness vs. Fatigue Life for Interference Fit Fasteners Only

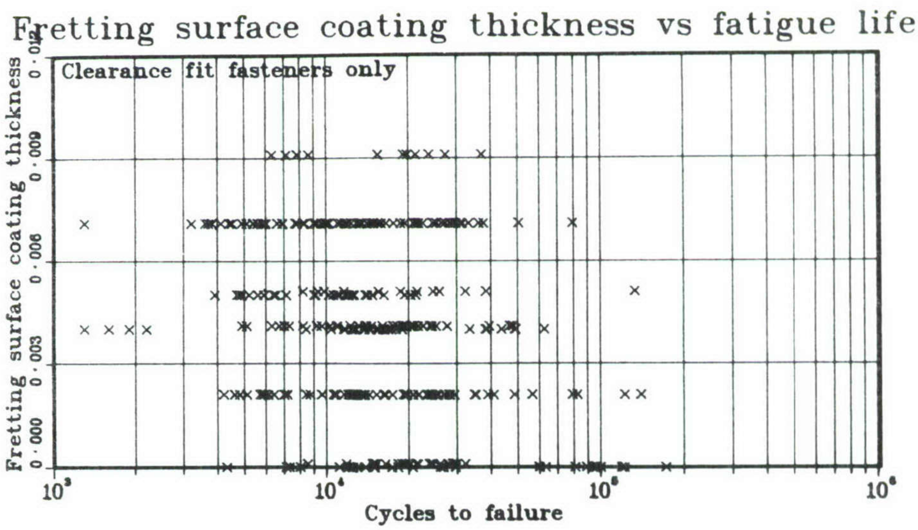

Figure 51. Fretting Surface Coating Thickness vs. Fatigue Life for Clearance Fit Fasteners Only

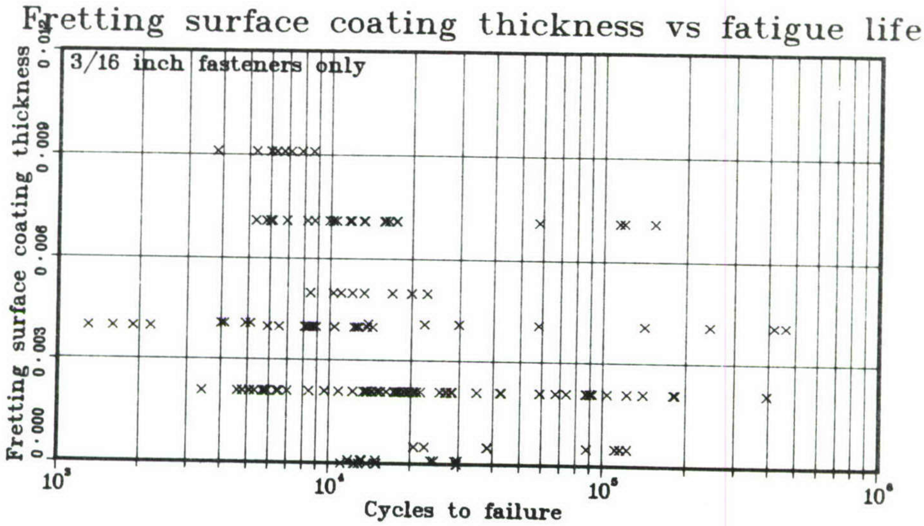

Figure 52. Fretting Surface Coating Thickness vs. Fatigue Life for 3/16-Inch Fasteners Only

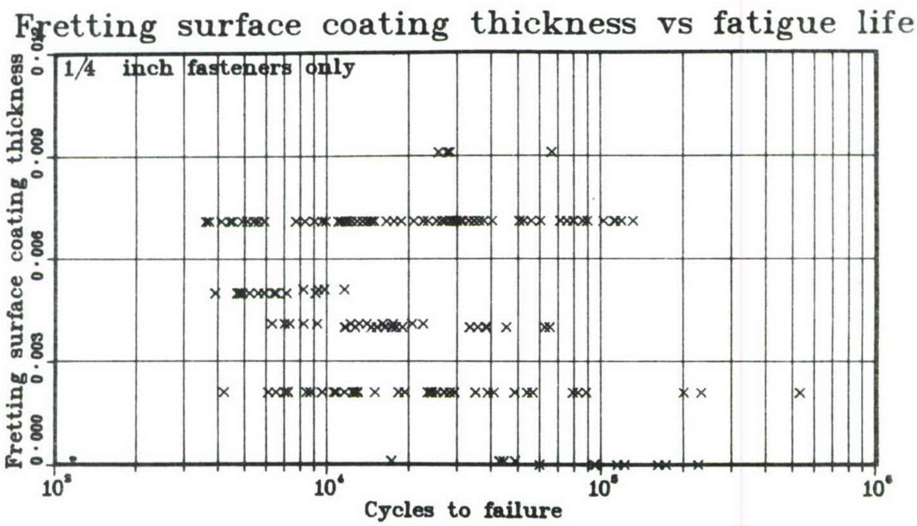

Figure 53. Fretting Surface Coating Thickness vs. Fatigue Life for 1/4-Inch Fasteners Only

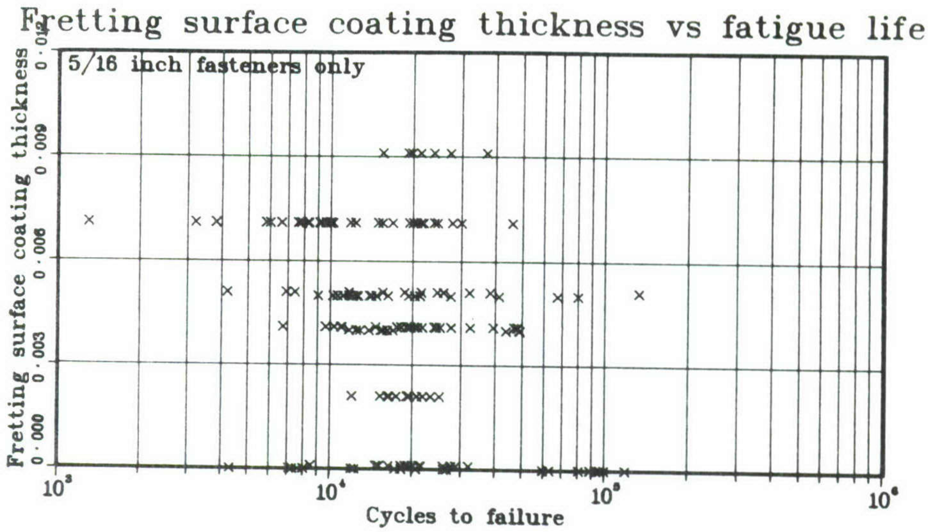

Figure 54. Fretting Surface Coating Thickness vs. Fatigue Life for 5/16-Inch Fasteners Only

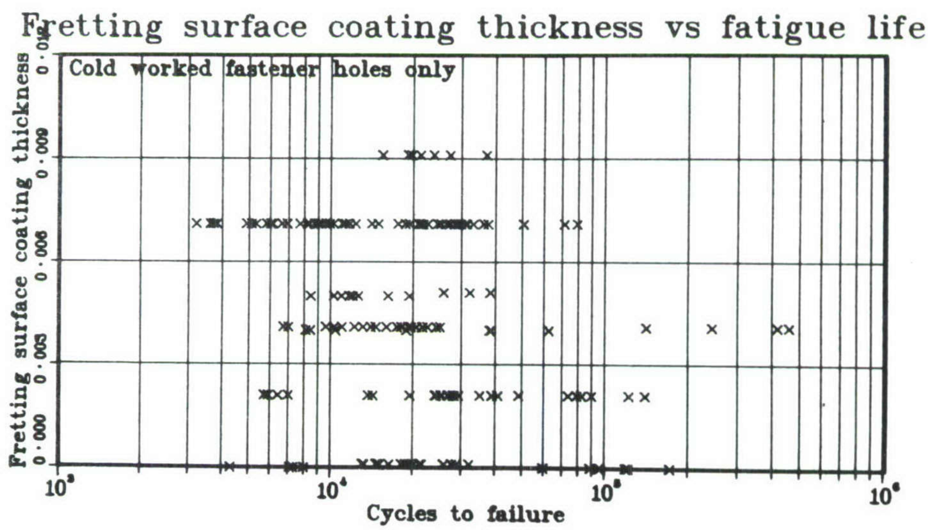

Figure 55. Fretting Surface Coating Thickness vs. Fatigue Life for Cold-Worked Fastener Holes Only

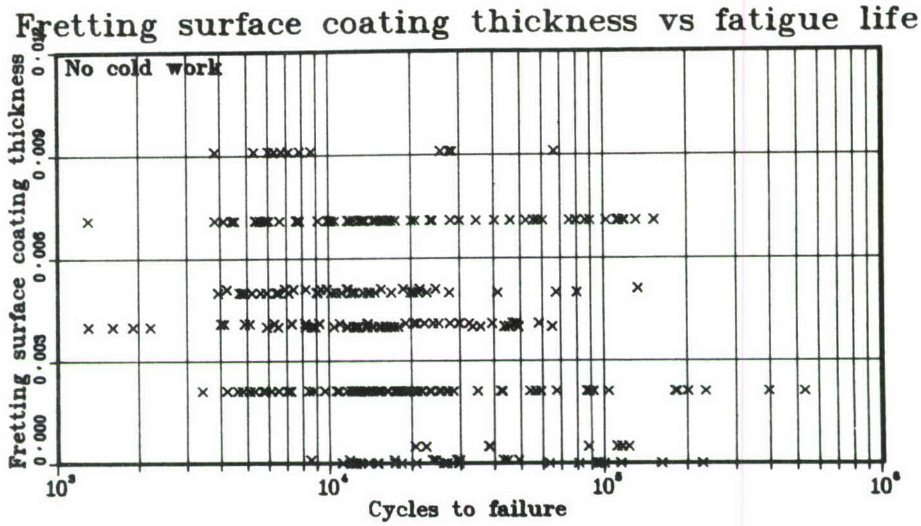

Figure 56. Fretting Surface Coating Thickness vs. Fatigue Life for No Cold-Work

It is interesting to note that the longest-lived specimen had a hole surface roughness of 225 microinches, and the shortest-lived specimen had a surface roughness of 75 microinches. The lack of correlation between hole surface roughness and fatigue life is shown in Figures 57 through 68.

g. Hole Angle Error

The difference between the hole centerline and the local perpendicular, measured in degrees, entered into a number of the models, and the negative value on the beta coefficient showed that angle error would serve to reduce fatigue life.

An examination of the residuals brought out that there was also a significant nonlinearity in this influence as the angle increased above 2°. Since 2° is a value found in some manufacturers process specifications for the allowable deviation from the perpendicular for some critical holes, this value seems fully justifiable and should be retained as manufacturing process limit.

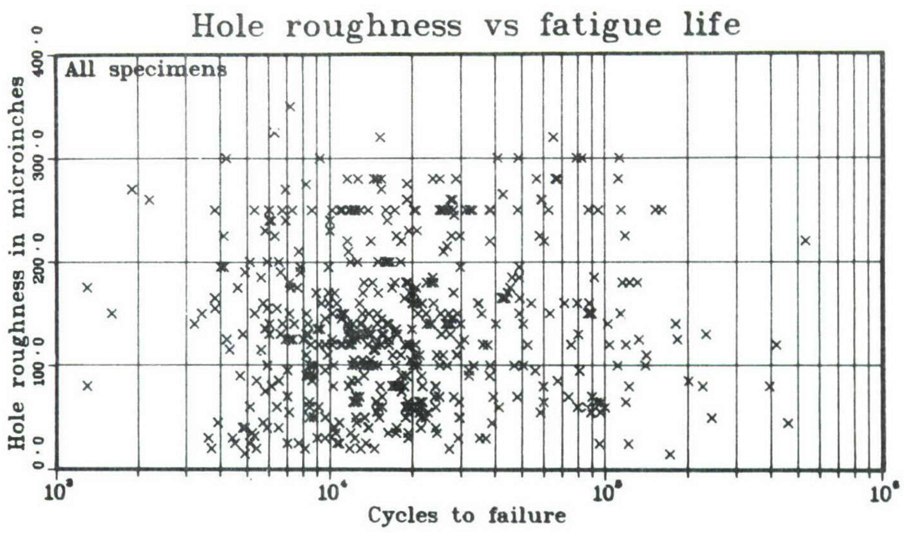

Figure 57. Hole Roughness vs. Fatigue Life for All Specimens

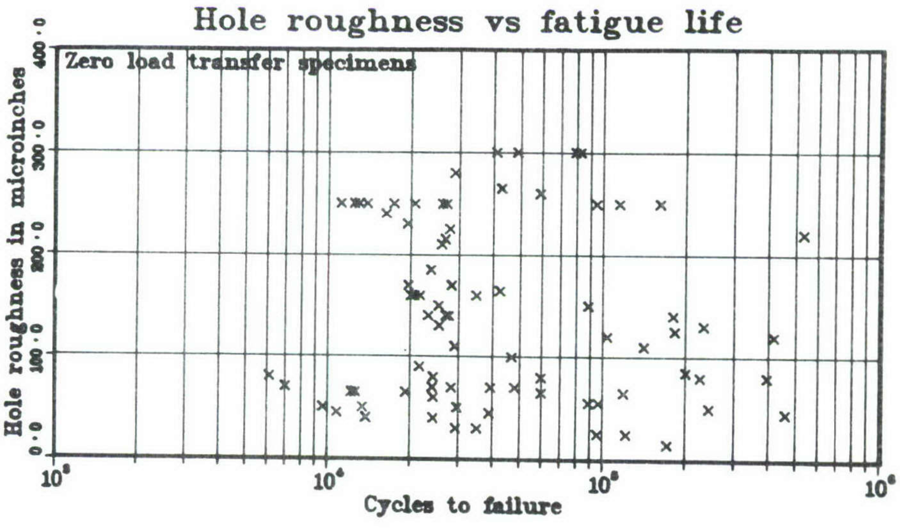

Figure 58. Hole Roughness vs. Fatigue Life for Zero Load Transfer Specimens

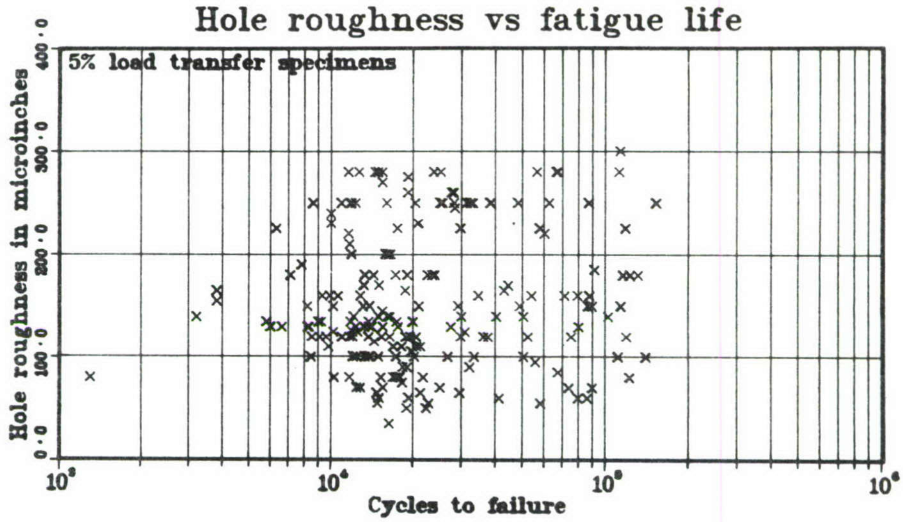

Figure 59. Hole Roughness vs. Fatigue Life for 5% Load Transfer Specimens

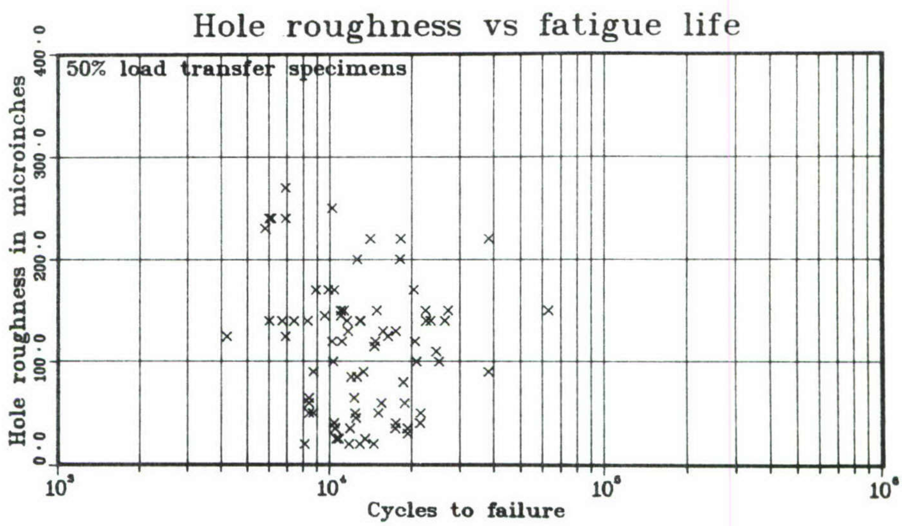

Figure 60. Hole Roughness vs. Fatigue Life for 50% Load Transfer Specimens

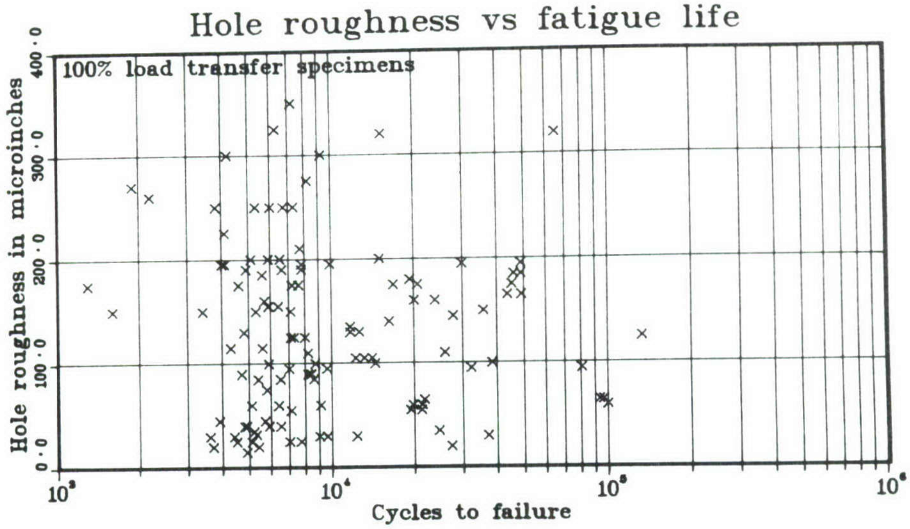

Figure 61. Hole Roughness vs. Fatigue Life for 100% Load Transfer Specimens

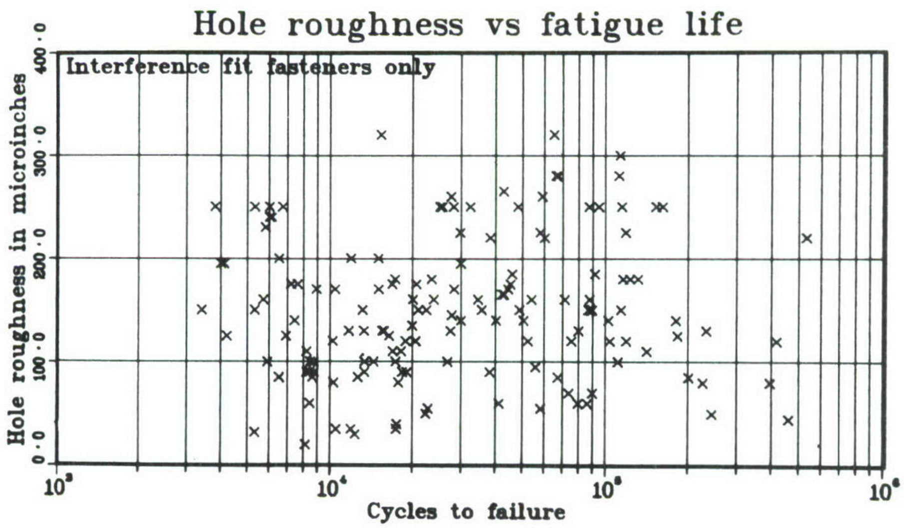

Figure 62. Hole Roughness vs. Fatigue Life for Interference Fit Fasteners Only

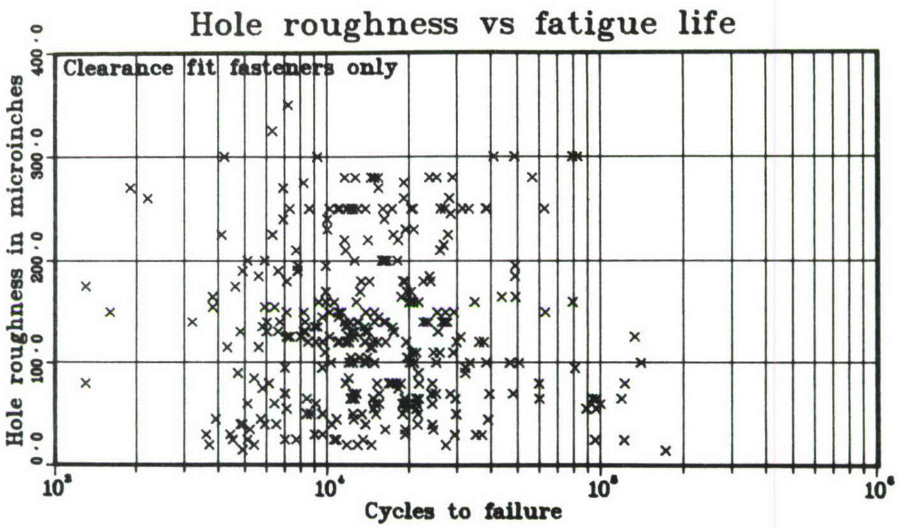

Figure 63. Hole Roughness vs. Fatigue Life for Clearance Fit Fasteners Only

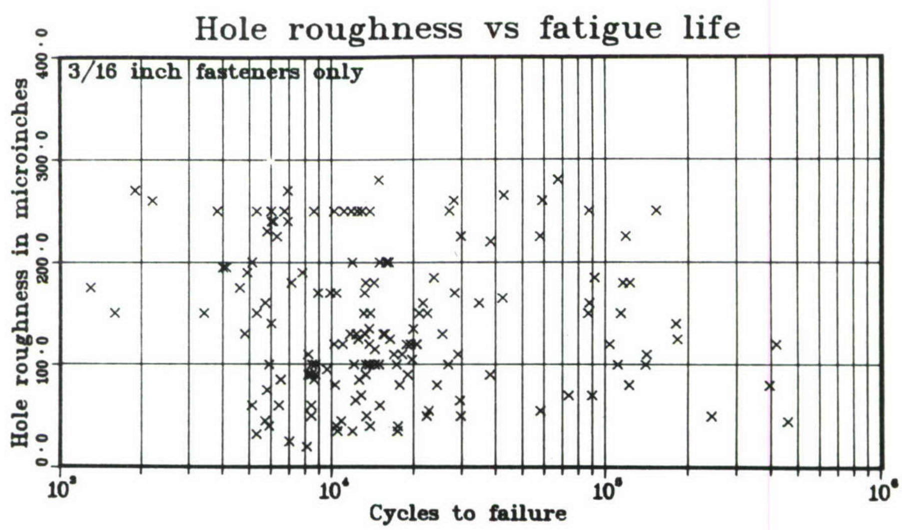

Figure 64. Hole Roughness vs. Fatigue Life for 3/16-Inch Fasteners Only

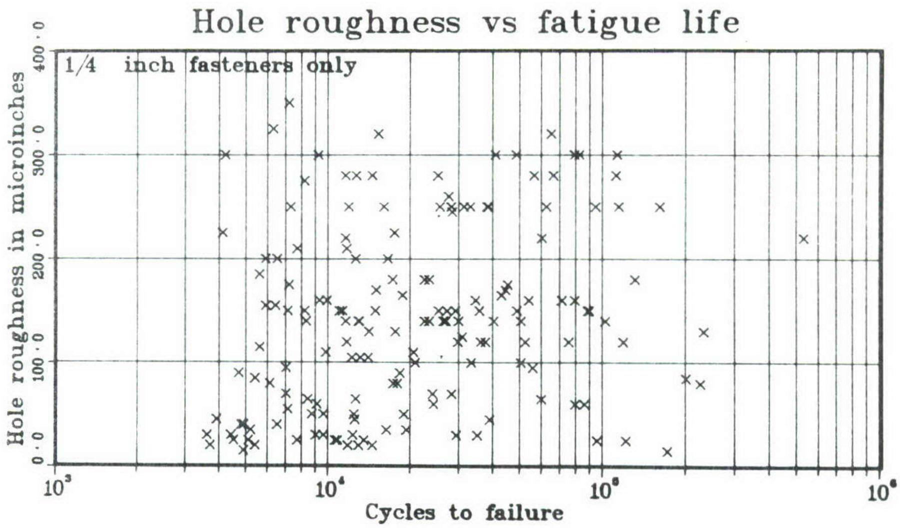

Figure 65. Hole Roughness vs. Fatigue Life for 1/4-Inch Fasteners Only

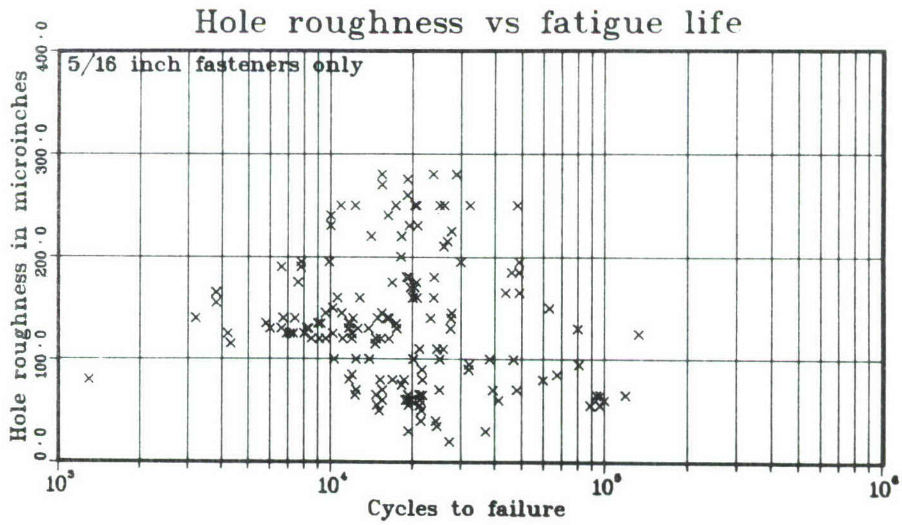

Figure 66. Hole Roughness vs. Fatigue Life for 5/16-Inch Fasteners Only

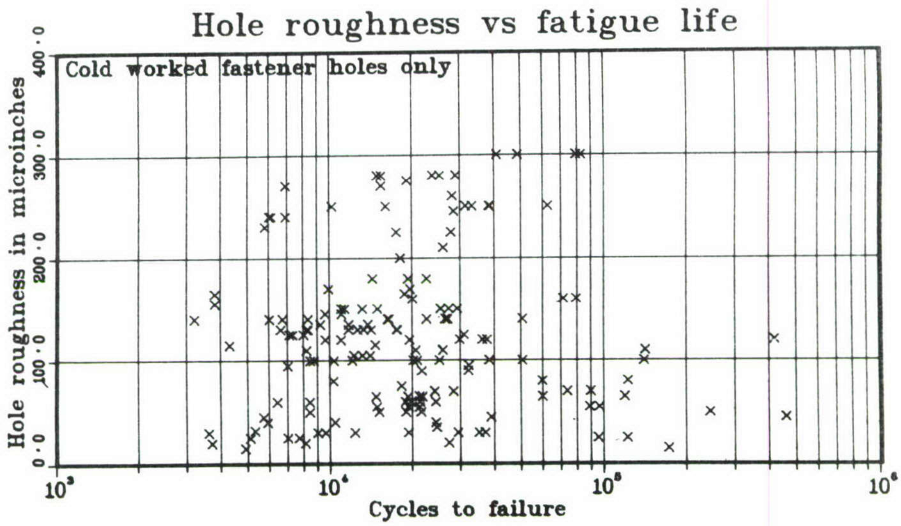

Figure 67. Hole Roughness vs. Fatigue Life for Cold-Worked Fastener Holes Only

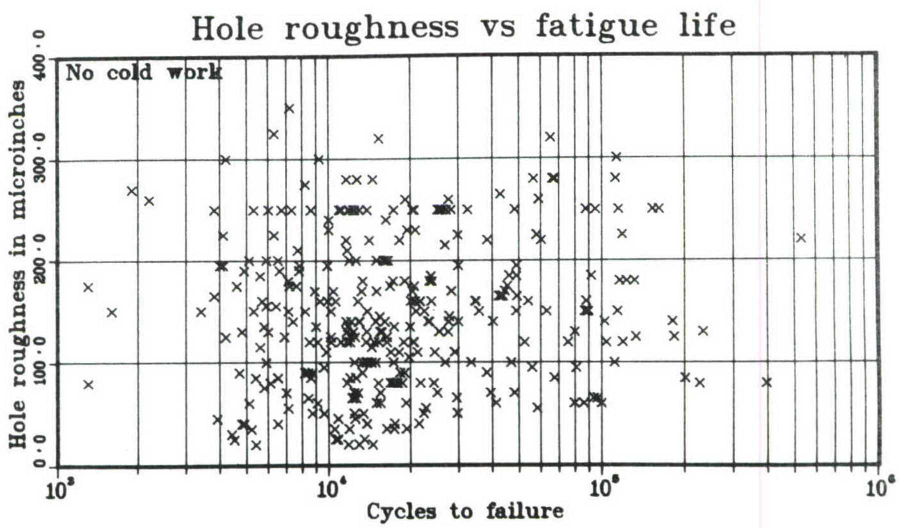

Figure 68. Hole Roughness vs. Fatigue Life for No Cold-Work

h. Countersink Angle Error

Like the countersink misalignment the countersink angle error did not have a strong role in the determination of fatigue life of the specimens. The hole angle error limits should be adequate for the control of countersink angle errors.

i. Hole Taper Angle

The hole taper angle in degrees was computed for each hole. The angle's role was checked using its value. However, a better fit was found when the mathematical absolute value was used. It plays a strong role in only the 100% load transfer model. Examining the specimens made it apparent that the thicker specimens offered more total change in hole diameter and given the role of fastener interference in enhancing fatigue life (discussed below), the hole taper angle was showing the change in interference that can occur in thicker specimens rather than any inherent property of a tapered hole. Since no tapered fasteners were included in this study (only tapered holes with straight fasteners) there is no way to resolve the efficacy of improperly matched taper angles beyond the argument given above on changes in interference. Hole taper effects are shown in Figures 69 through 80.

j. Hole Straightness Deviation

The effect of hole straightness deviation was not significant in most of the models. In the cases where it was significant, curved holes served to enhance fatigue life. This may be because, if the hole is not straight, a straight fastener in the hole is forced into interference with the hole. Therefore, what seems to be an increase in specimen fatigue life may be attributable to the benefits of interference. The influence of straightness deviation is shown in Figures 81 through 92.

k. Cold Work

Hole cold-work, measured in inches, came into many of the models and always enhanced fatigue life. This is consistent with the findings of Lindh and Phillips in their conclusions that cold-working helped extend fatigue life (Reference 67). The work they did in other alloys

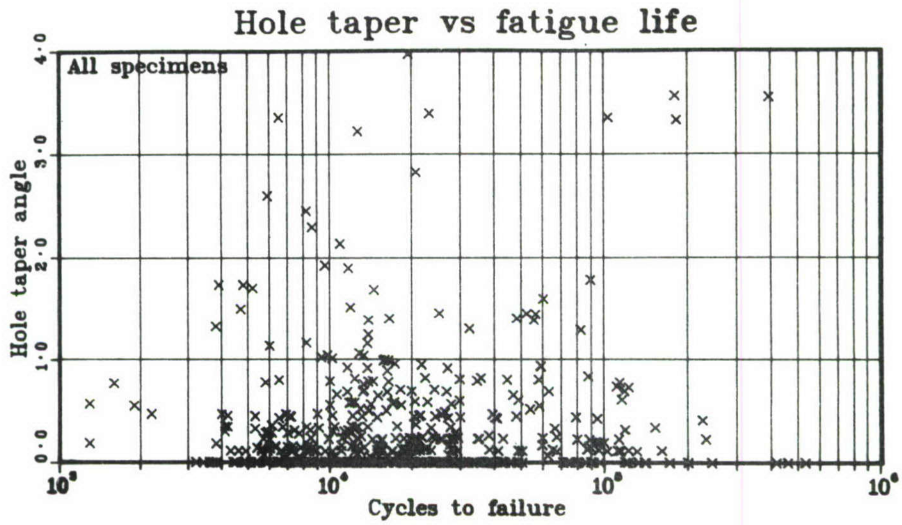

Figure 69. Hole Taper vs. Fatigue Life for All Specimens

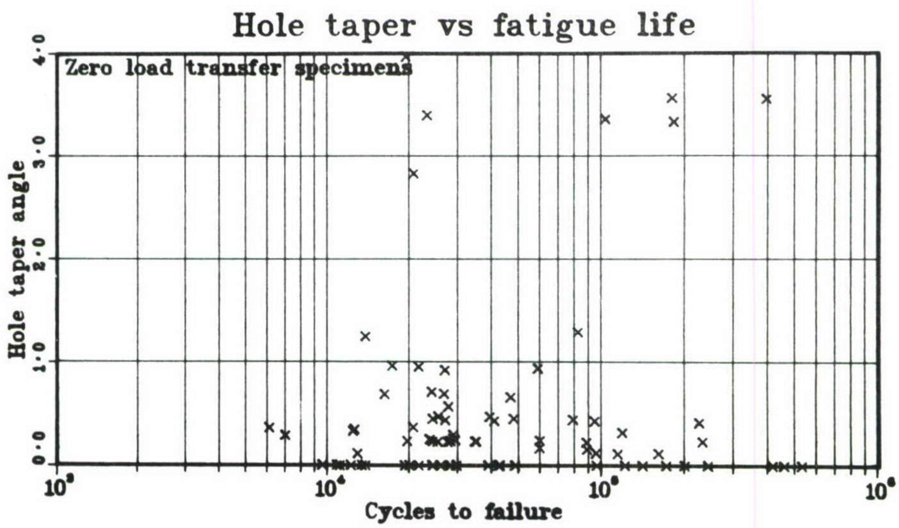

Figure 70. Hole Taper vs. Fatigue Life for Zero Load Transfer Specimens

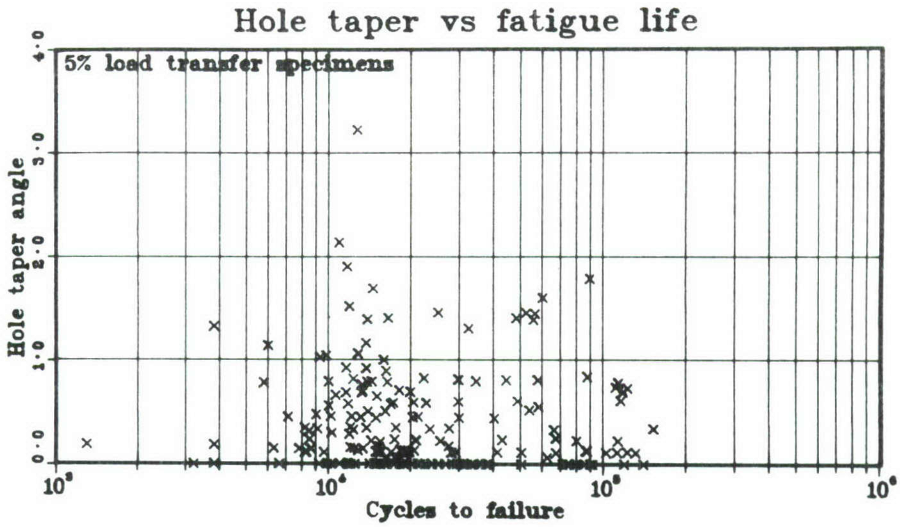

Figure 71. Hole Taper vs. Fatigue Life for 5% Load Transfer Specimens

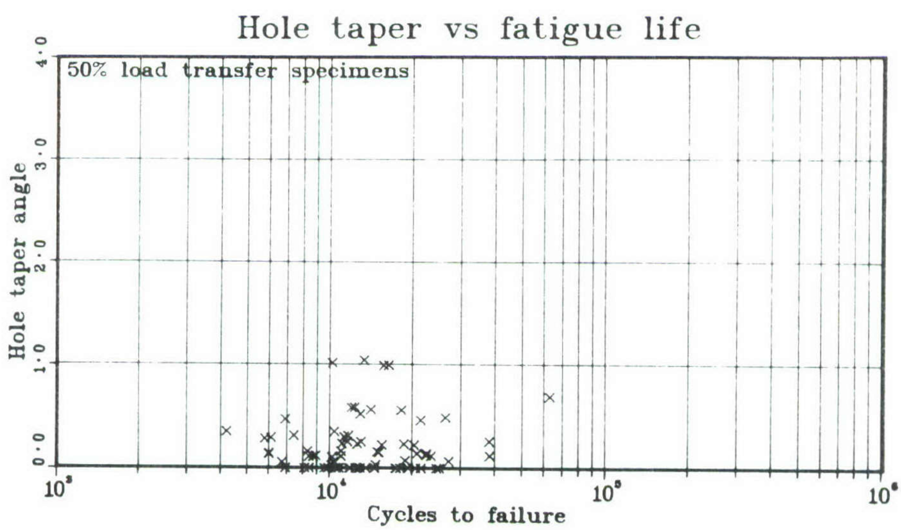

Figure 72. Hole Taper vs. Fatigue Life for 50% Load Transfer Specimens

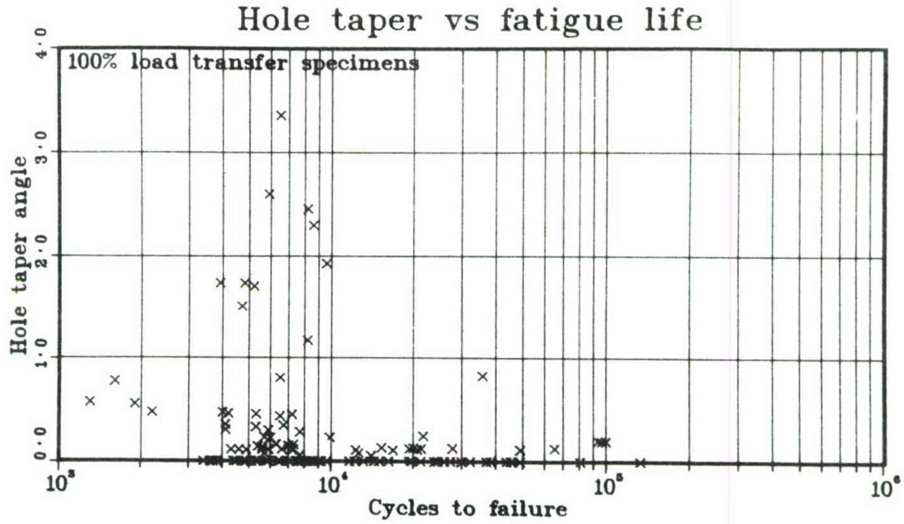

Figure 73. Hole Taper vs. Fatigue Life for 100% Load Transfer Specimens

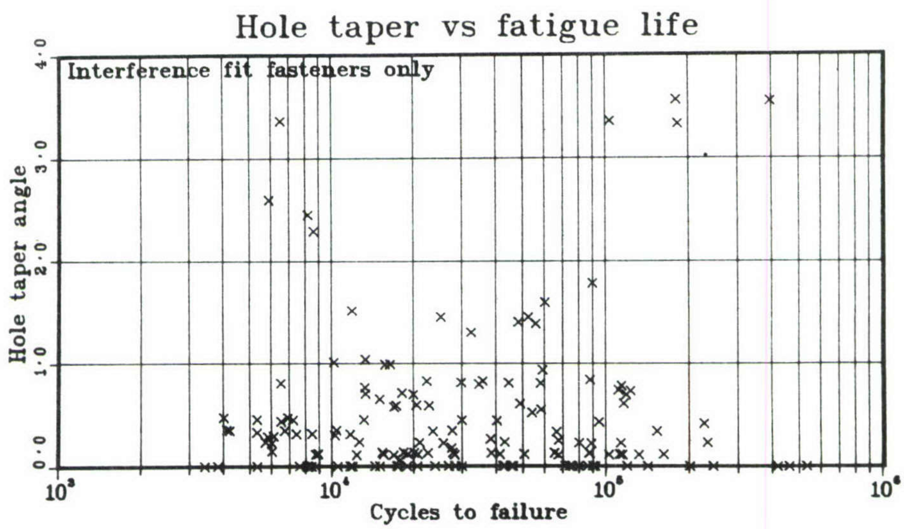

Figure 74. Hole Taper vs. Fatigue Life for Interference Fit Fasteners Only

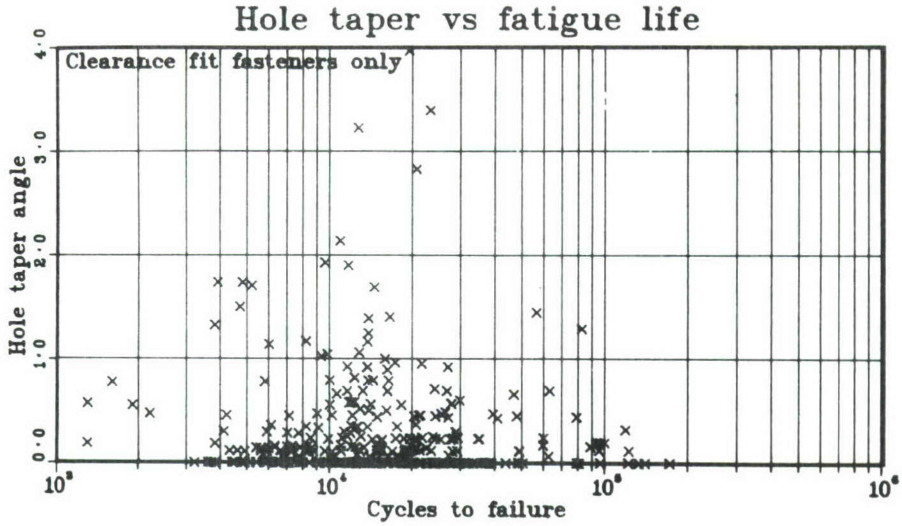

Figure 75. Hole Taper vs. Fatigue Life for Clearance Fit Fasteners Only

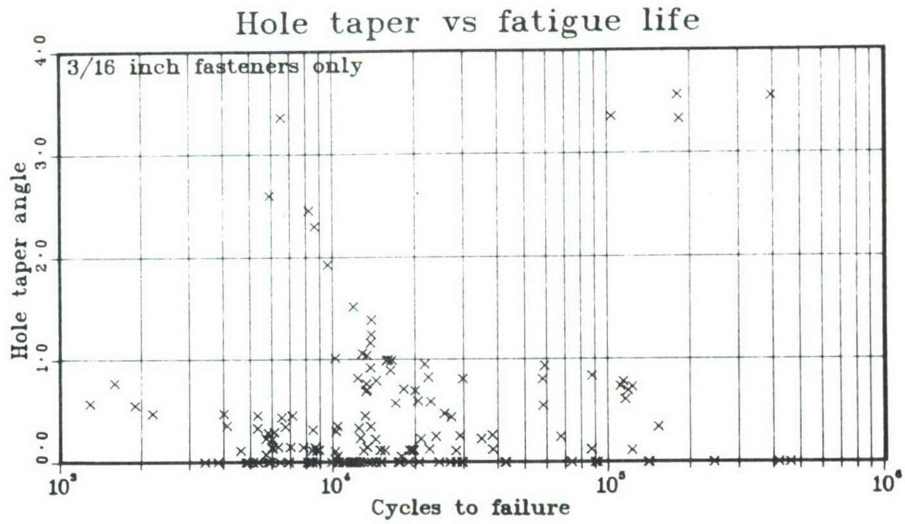

Figure 76. Hole Taper vs. Fatigue Life for 3/16-Inch Fasteners Only

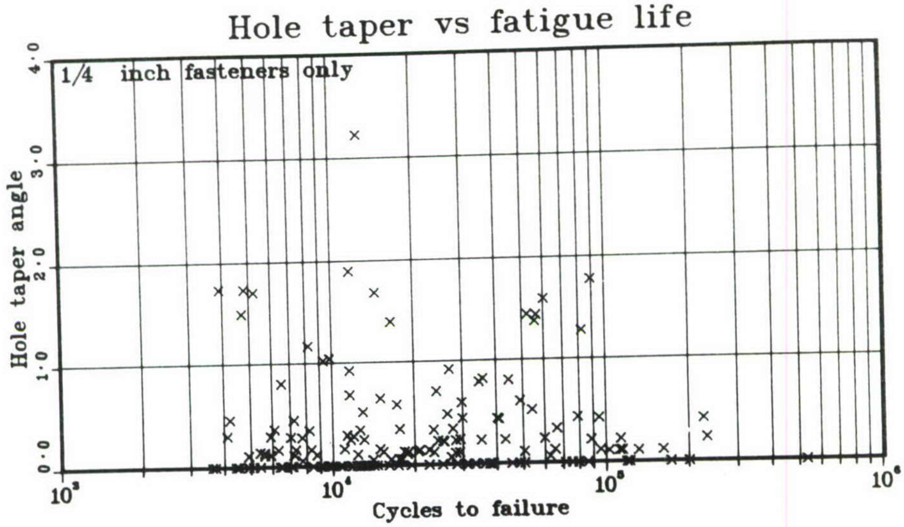

Figure 77. Hole Taper vs. Fatigue Life for 1/4-Inch Fasteners Only

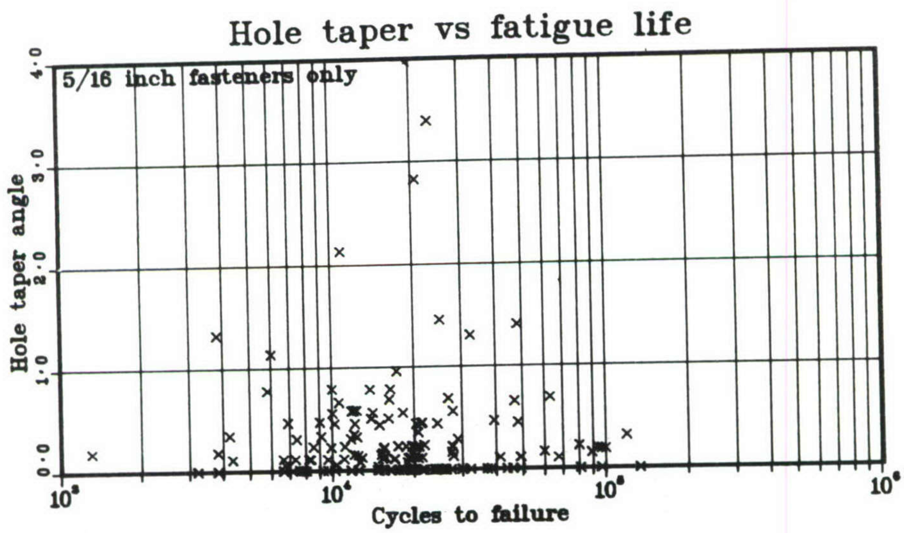

Figure 78. Hole Taper vs. Fatigue Life for 5/16-Inch Fasteners Only

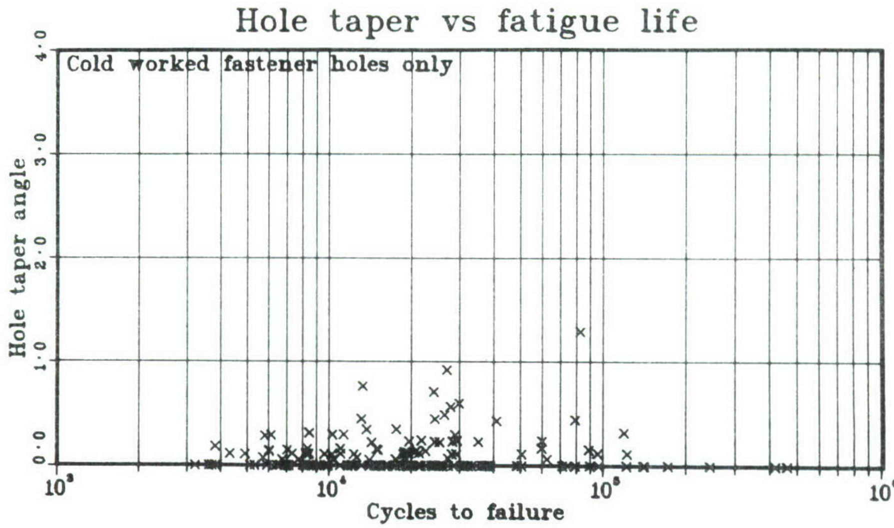

Figure 79. Hole Taper vs. Fatigue Life for Cold-Worked Fastener Holes Only

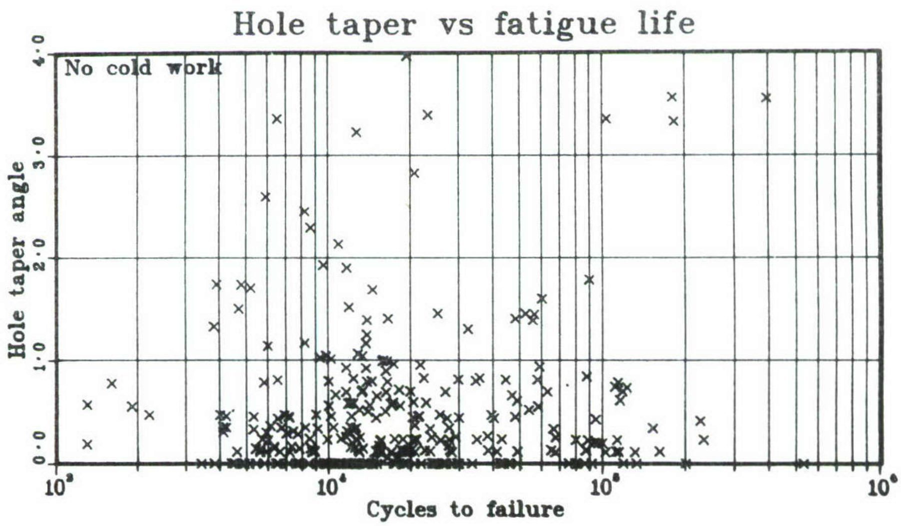

Figure 80. Hole Taper vs. Fatigue Life for No Cold-Work

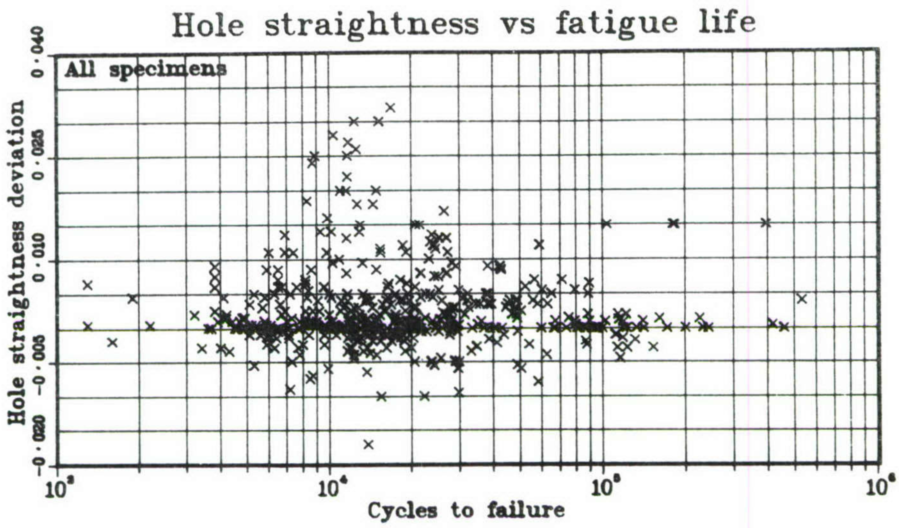

Figure 81. Hole Straightness vs. Fatigue Life for All Specimens

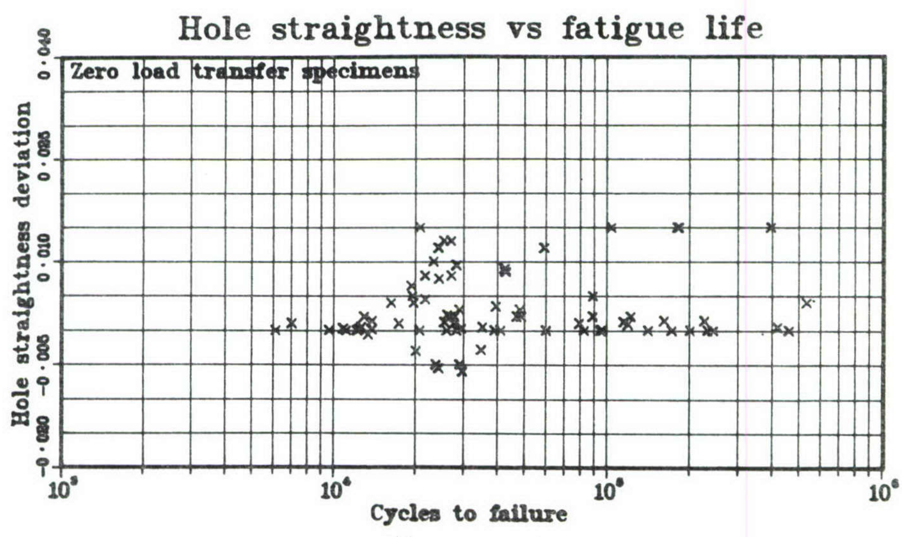

Figure 82. Hole Straightness vs. Fatigue Life for Zero Load Transfer Specimens

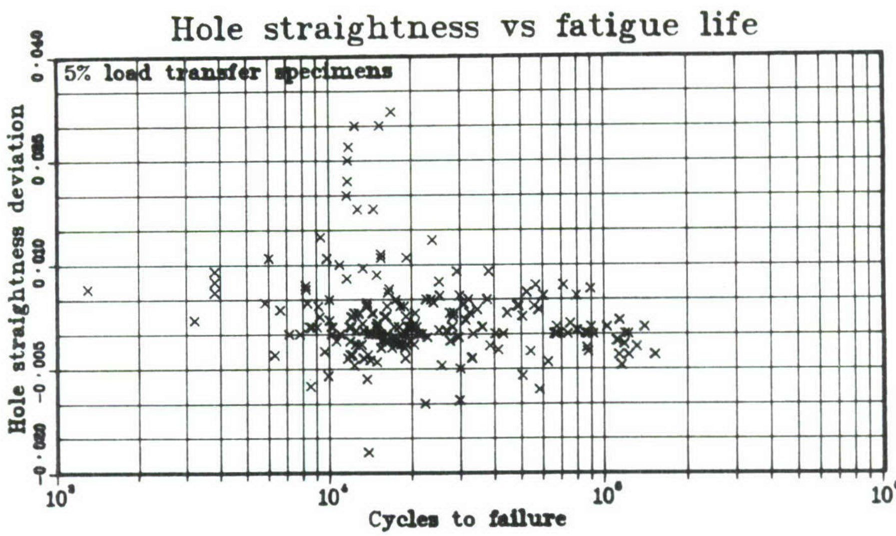

Figure 83. Hole Straightness vs. Fatigue Life for 5% Load Transfer Specimens

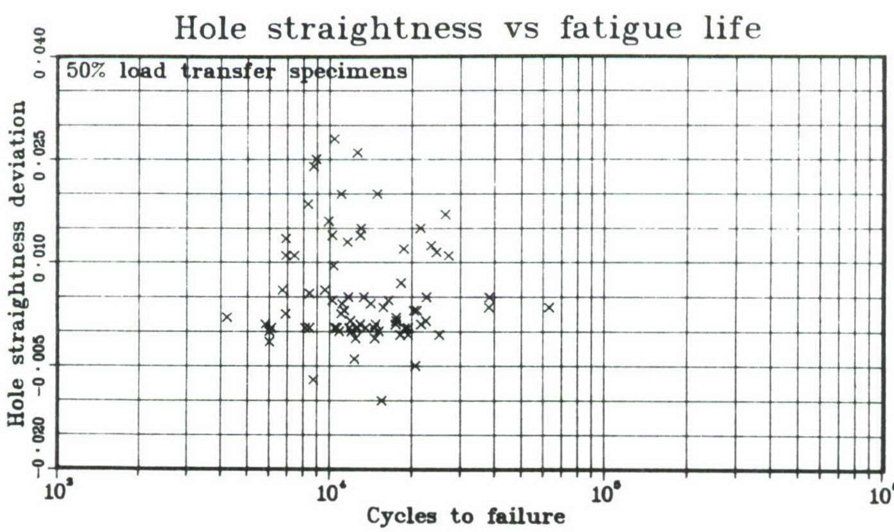

Figure 84. Hole Straightness vs. Fatigue Life for 50% Load Transfer Specimens

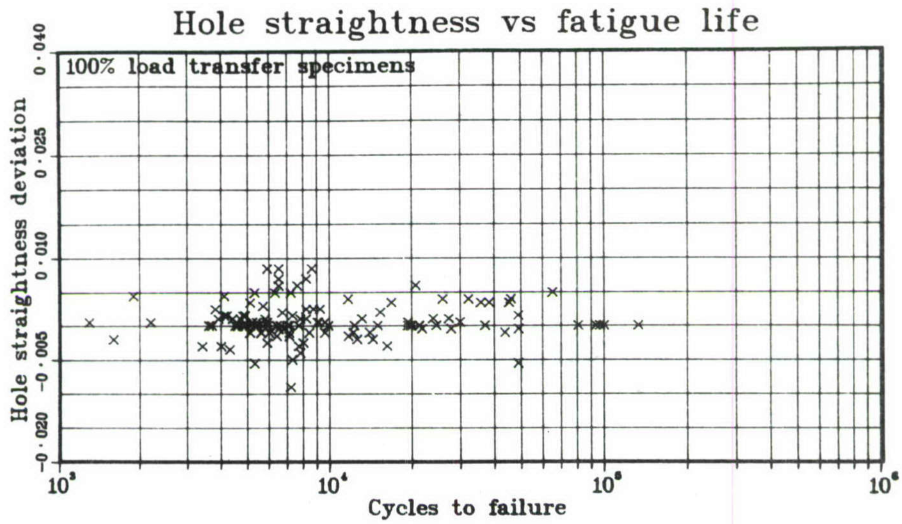

Figure 85. Hole Straightness vs. Fatigue Life for 100% Load Transfer Specimens

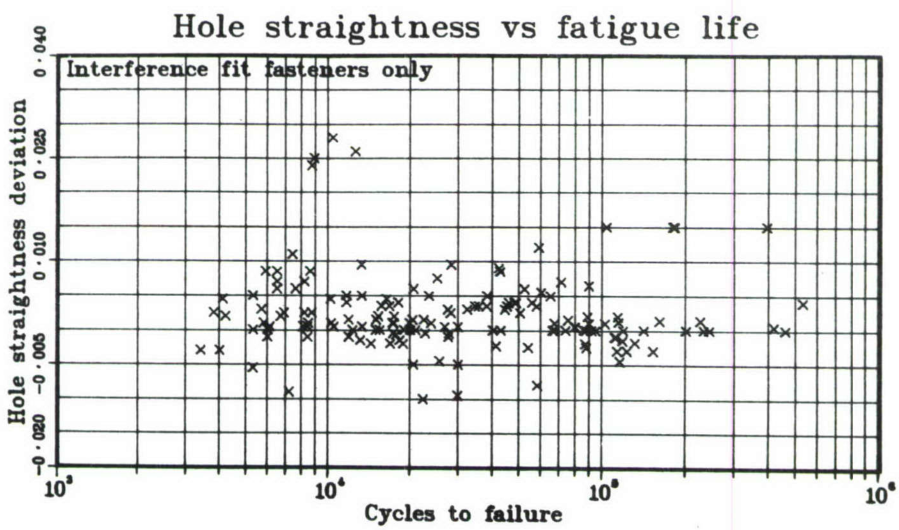

Figure 86. Hole Straightness vs. Fatigue Life for Interference Fit Fasteners Only

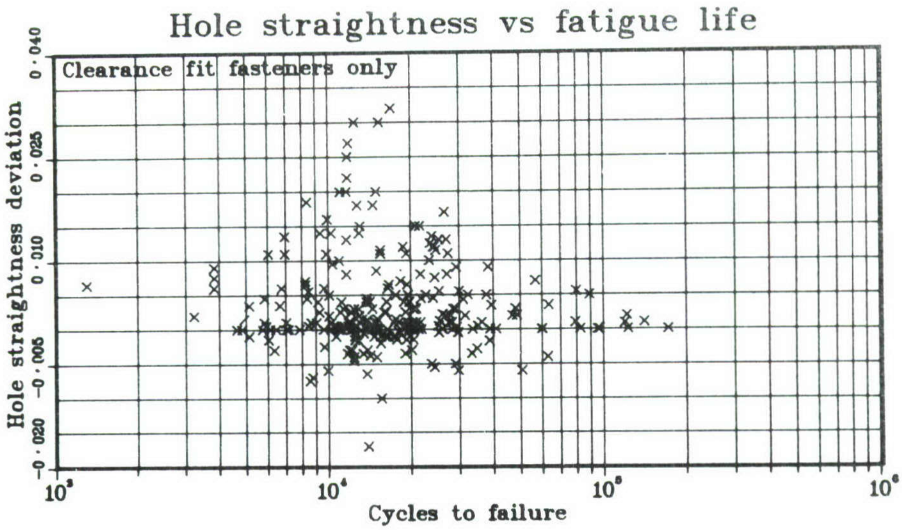

Figure 87. Hole Straightness vs. Fatigue Life for Clearance Fit Fasteners Only

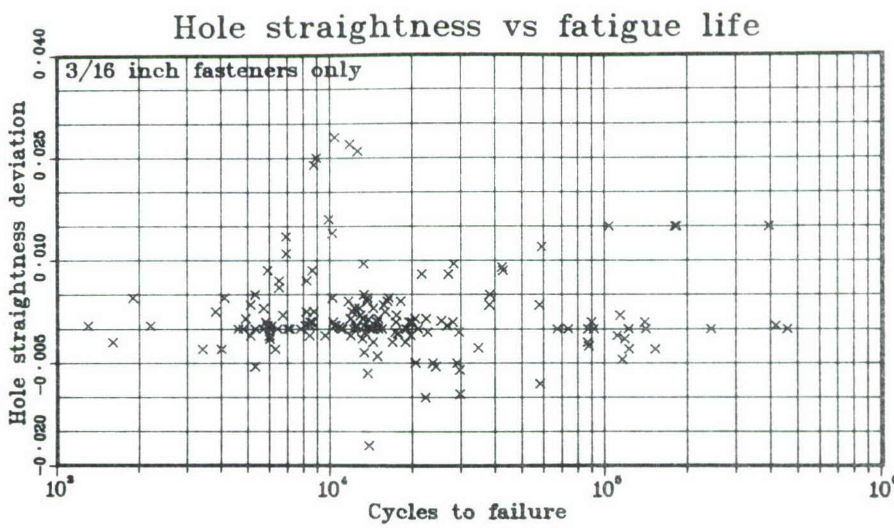

Figure 88. Hole Straightness vs. Fatigue Life for 3/16-Inch Fasteners Only

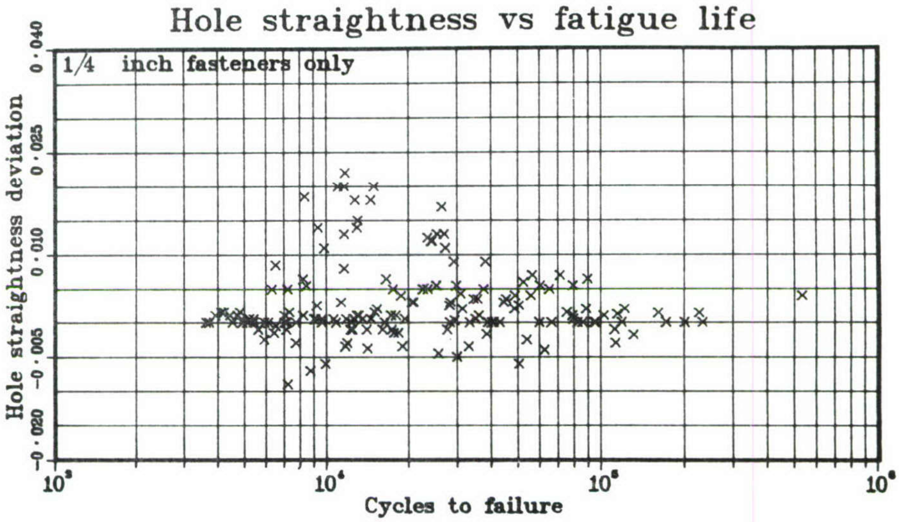

Figure 89. Hole Straightness vs. Fatigue Life for 1/4-Inch Fasteners Only

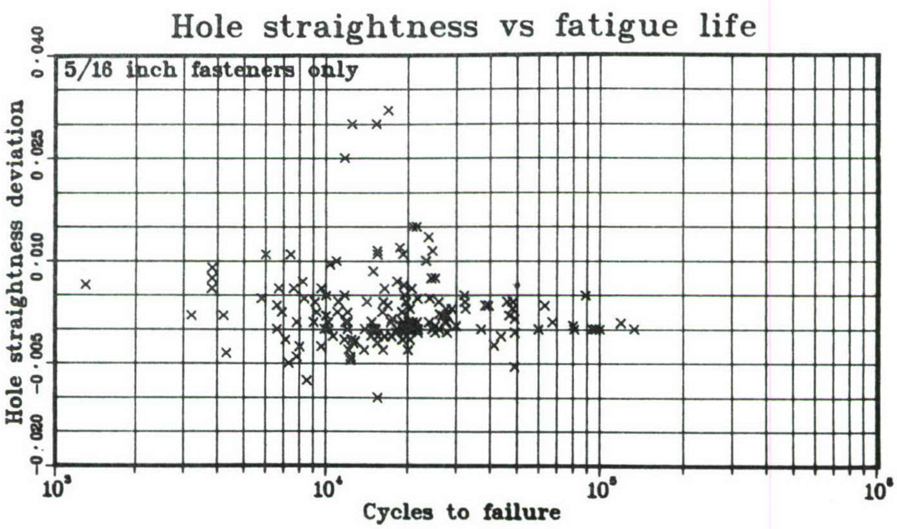

Figure 90. Hole Straightness vs. Fatigue Life for 5/16-Inch Fasteners Only

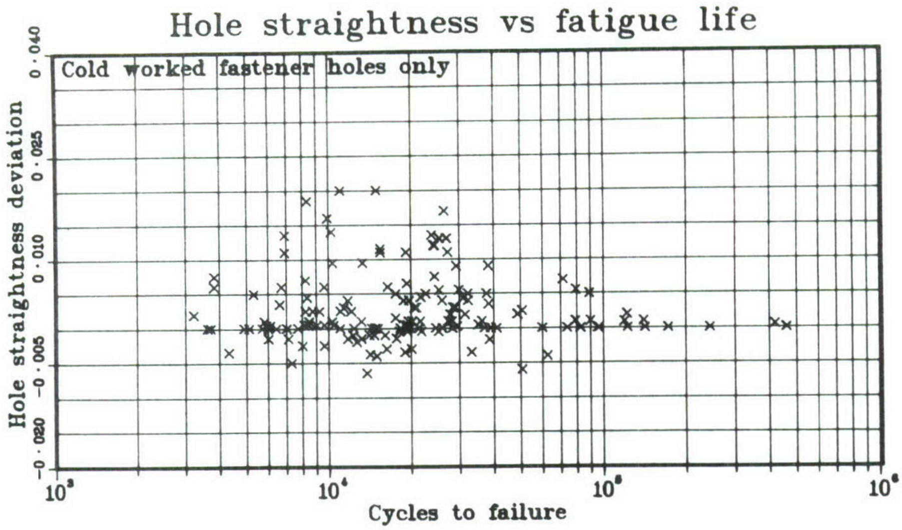

Figure 91. Hole Straightness vs. Fatigue Life for Cold-Worked Fastener Holes Only

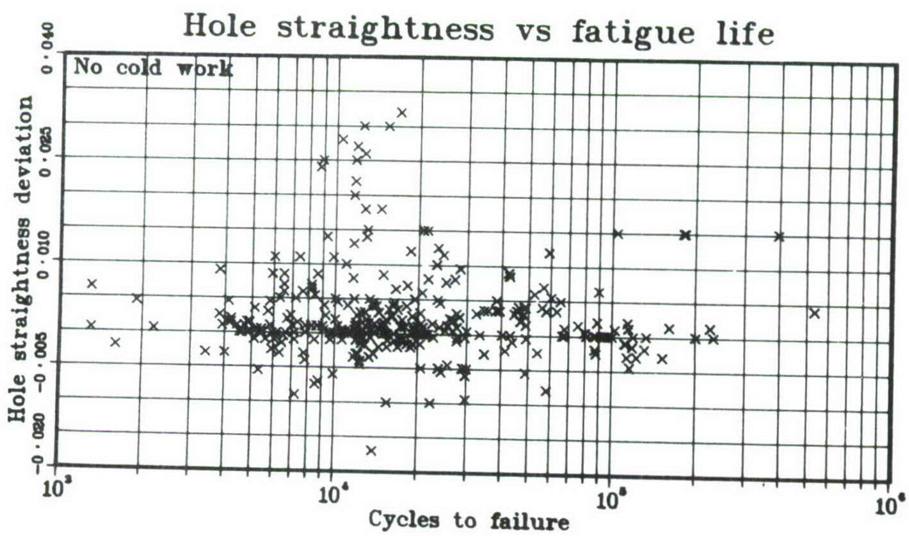

Figure 92. Hole Straightness vs. Fatigue Life for No Cold-Work

would also seem valid for this material. Since there were no precracked specimens, there was no check on the effectiveness of cold-working in slowing or stopping crack growth in this material. This would be an excellent research opportunity in view of the use of 2219-T851 in long-lived (hopefully) structures where repairs for fatigue damage might someday be required.

One problem that was noted with the cold-working sleeves in the original batch used was that a large number of them, perhaps 40%, split on installation. After discussions with the manufacturer, it was concluded that this splitting resulted from defects in several of the batches used for this program. Some additional sleeves were provided by the manufacturer, and the splitting did not recur. On those specimens having split sleeves installed, the fatigue crack usually began at the split in the sleeve. The effects of cold-work are shown in Figures 93 through 102.

l. Fastener Interference

Fastener interference, measured in inches and based on hole and fastener diameter, entered into almost all of the models developed. Interestingly, its coefficients are frequently two to three times the coefficients for cold-working. This means that if the same physical amounts of cold-work or interference are available, the interference would be more effective in increasing fatigue life.

It is also worth noting that in the 50% load transfer model, interference decreases fatigue life (Figure 106). One possible reason for this is that the residual tensile hoop stresses around the fastener hole may react with the bending stresses present because of the asymmetry of the specimen to increase the peak stresses and yield earlier failure. Interference effects are shown in Figures 103 through 114.

m. Fastener Removal

Fastener removal was coded as -1. for removal and 1. for the cases when no removal occurred. The coefficient shown in the models would have to be either added in the case of a specimen with no fastener

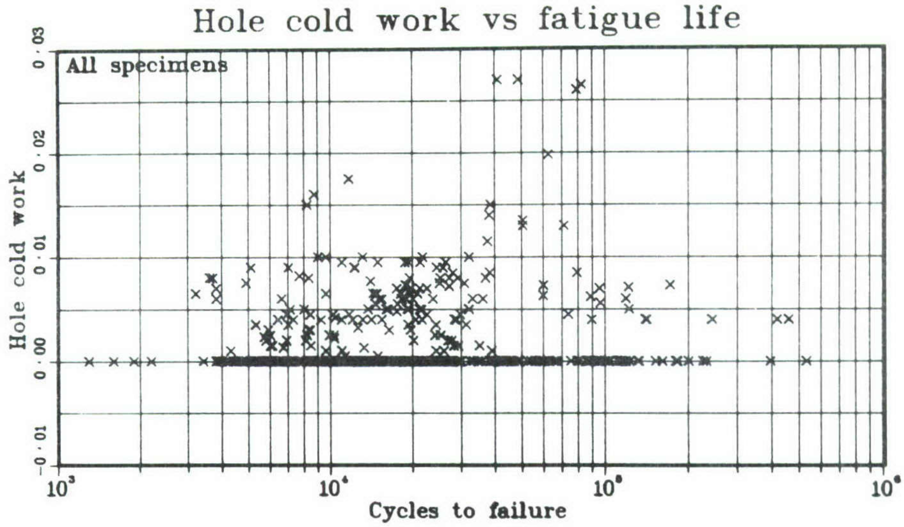

Figure 93. Hole Cold-Work vs. Fatigue Life for All Specimens

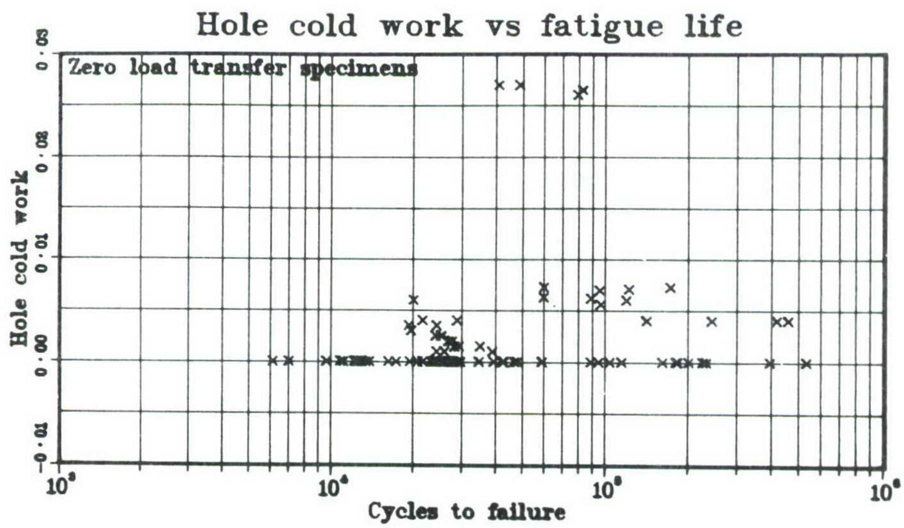

Figure 94. Hole Cold-Work vs. Fatigue Life for Zero Load Transfer Specimens

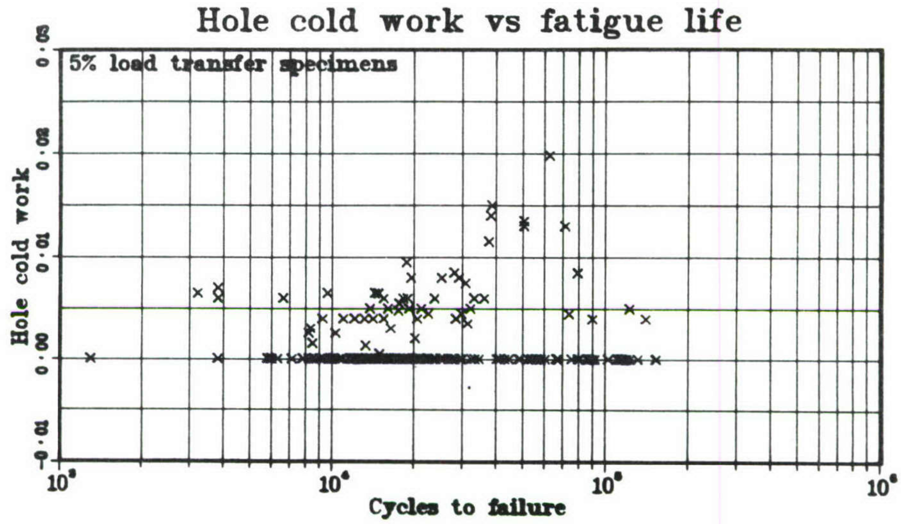

Figure 95. Hole Cold-Work vs. Fatigue Life for 5% Load Transfer Specimens

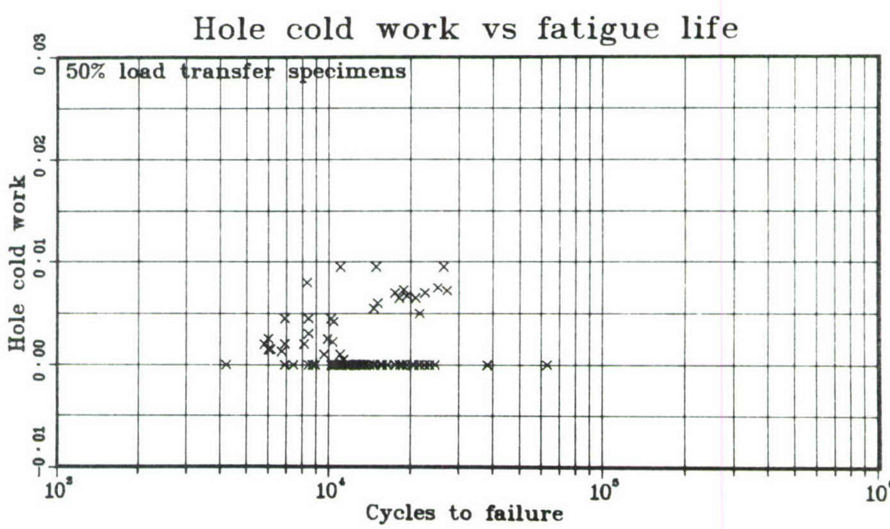

Figure 96. Hole Cold-Work vs. Fatigue Life for 50% Load Transfer Specimens

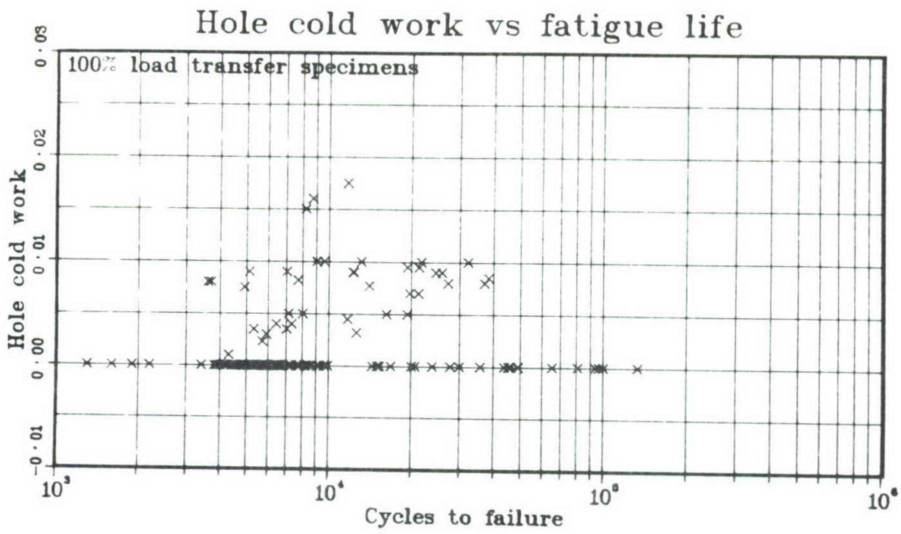

Figure 97. Hole Cold-Work vs. Fatigue Life for 100% Load Transfer Specimens

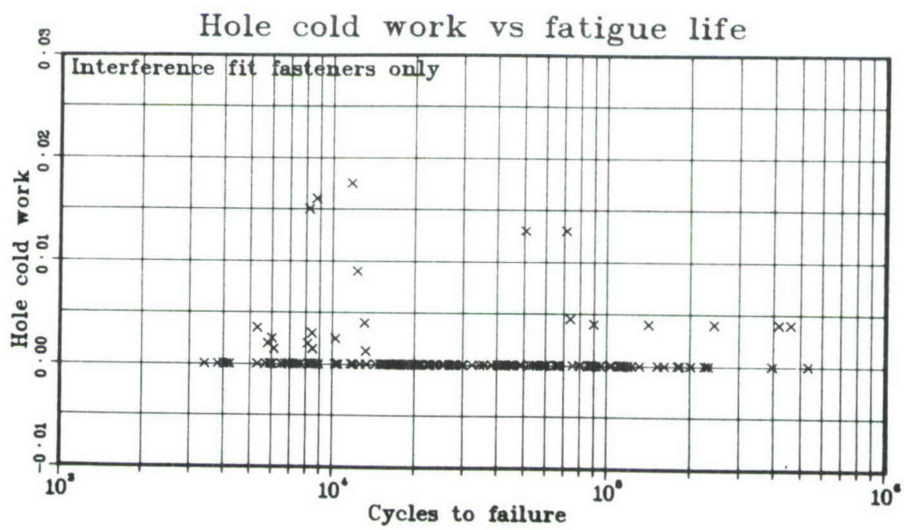

Figure 98. Hole Cold-Work vs. Fatigue Life for Interference Fit Fasteners Only

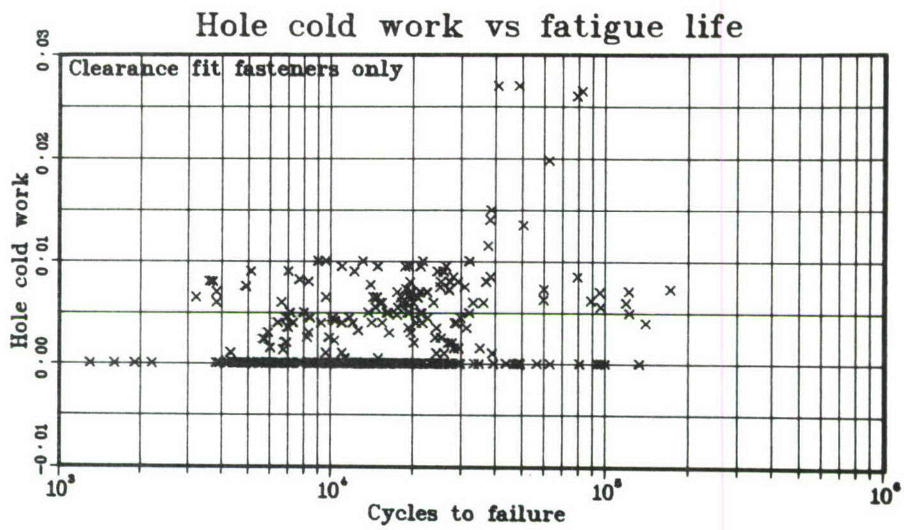

Figure 99. Hole Cold-Work vs. Fatigue Life for Clearance Fit Fasteners Only

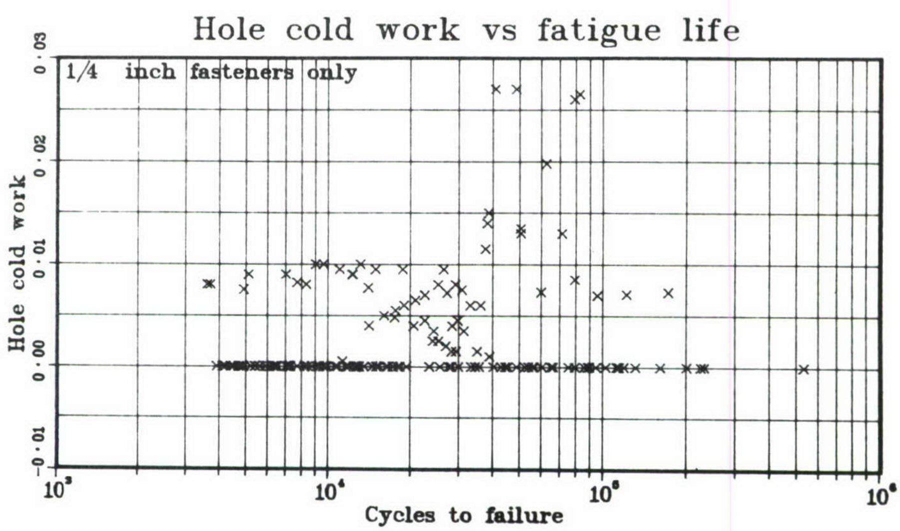

Figure 100. Hole Cold-Work vs. Fatigue Life for 1/4-Inch Fasteners Only

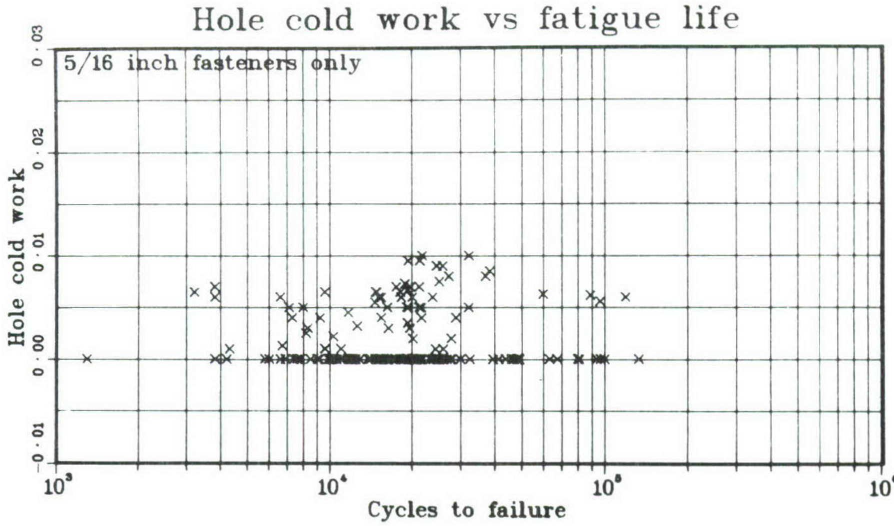

Figure 101. Hole Cold-Work vs. Fatigue Life for 5/16-Inch Fasteners Only

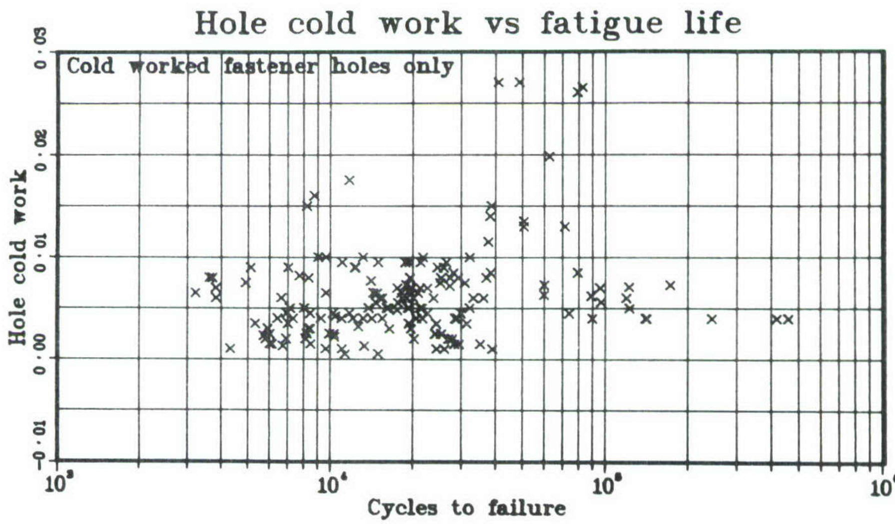

Figure 102. Hole Cold-Work vs. Fatigue Life for Cold-Worked Fastener Holes Only

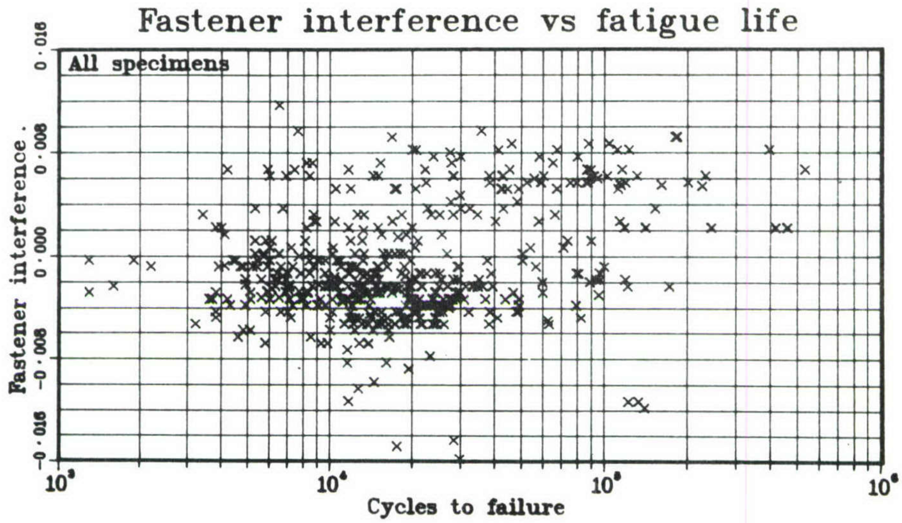

Figure 103. Fastener Interference vs. Fatigue Life for All Specimens

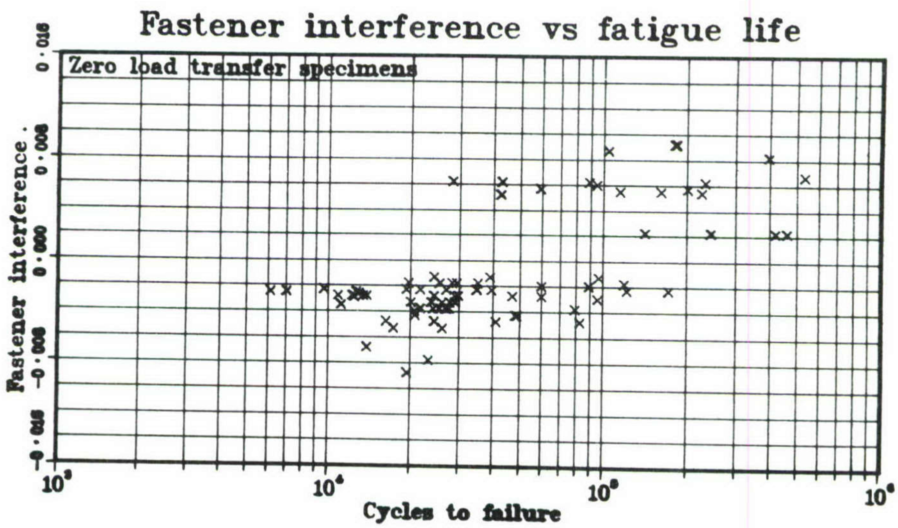

Figure 104. Fastener Interference vs. Fatigue Life for Zero Load Transfer Specimens

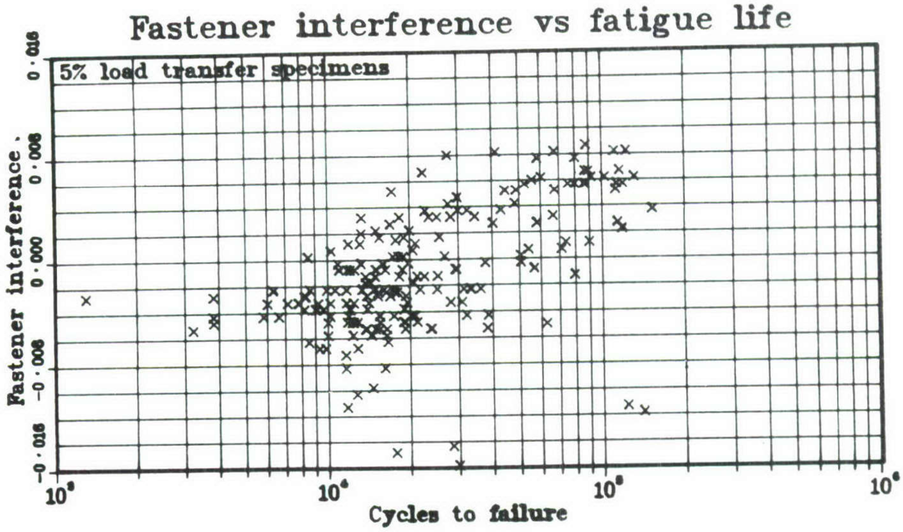

Figure 105. Fastener Interference vs. Fatigue Life for 5% Load Transfer Specimens

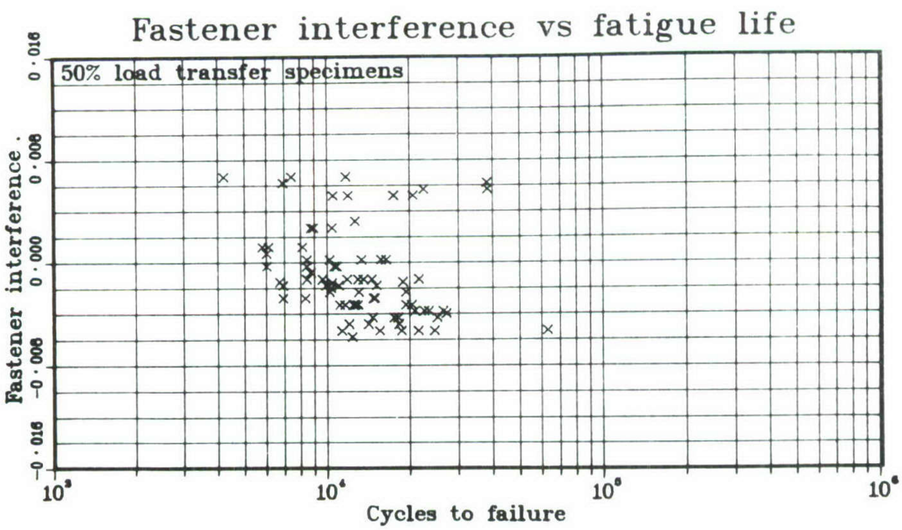

Figure 106. Fastener Interference vs. Fatigue Life for 50% Load Transfer Specimens

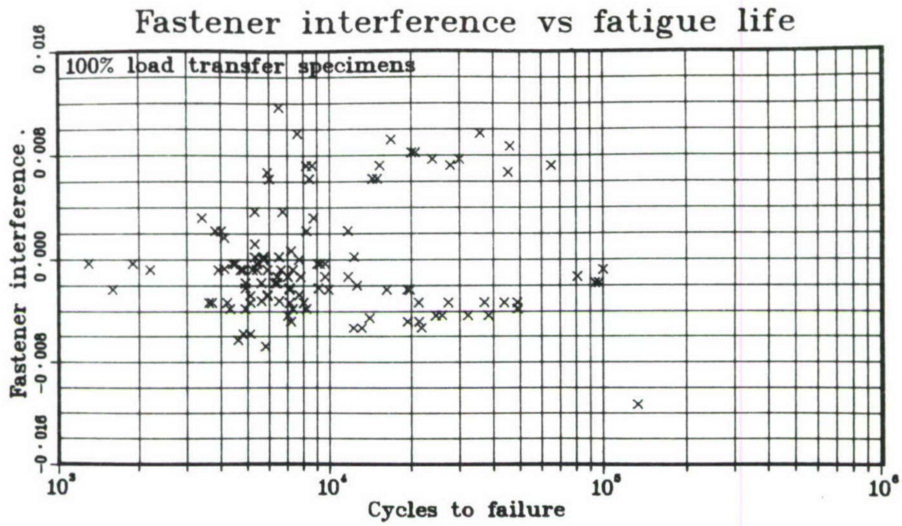

Figure 107. Fastener Interference vs. Fatigue Life for 100% Load Transfer Specimens

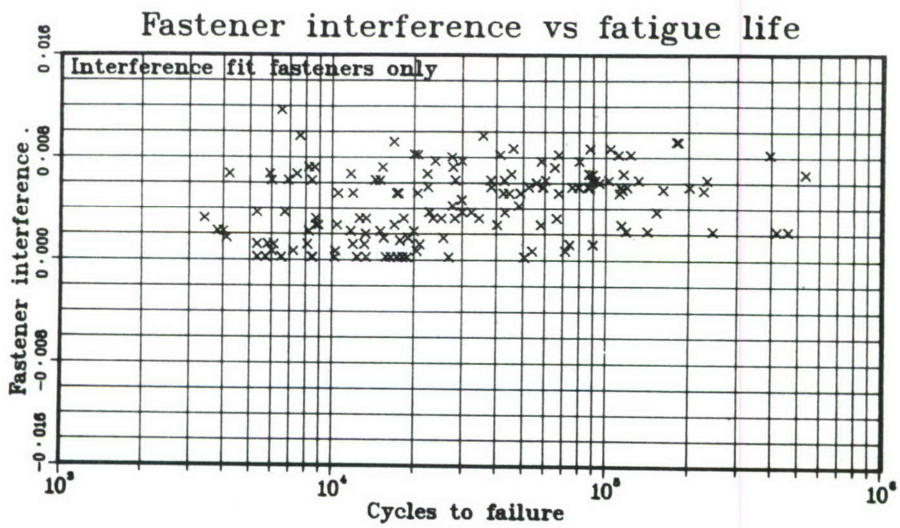

Figure 108. Fastener Interference vs. Fatigue Life for Interference Fit Fasteners Only

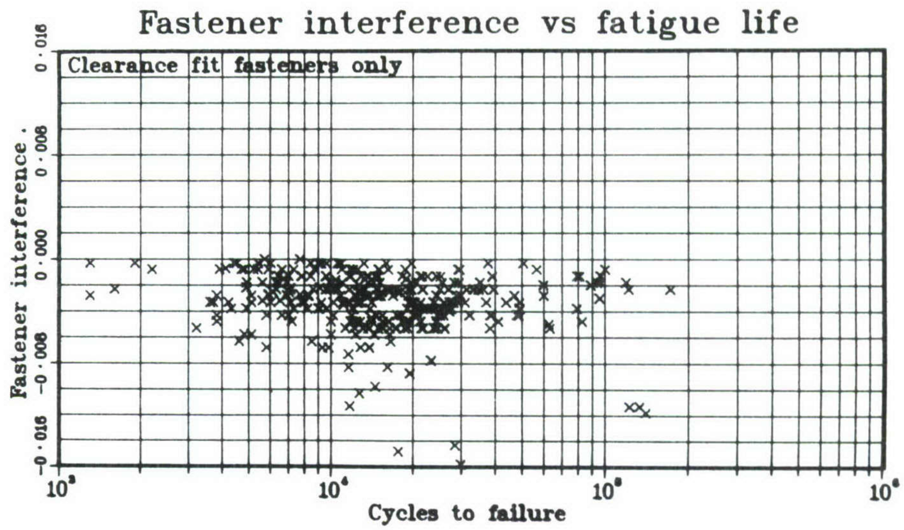

Figure 109. Fastener Interference vs. Fatigue Life for Clearance Fit Fasteners Only

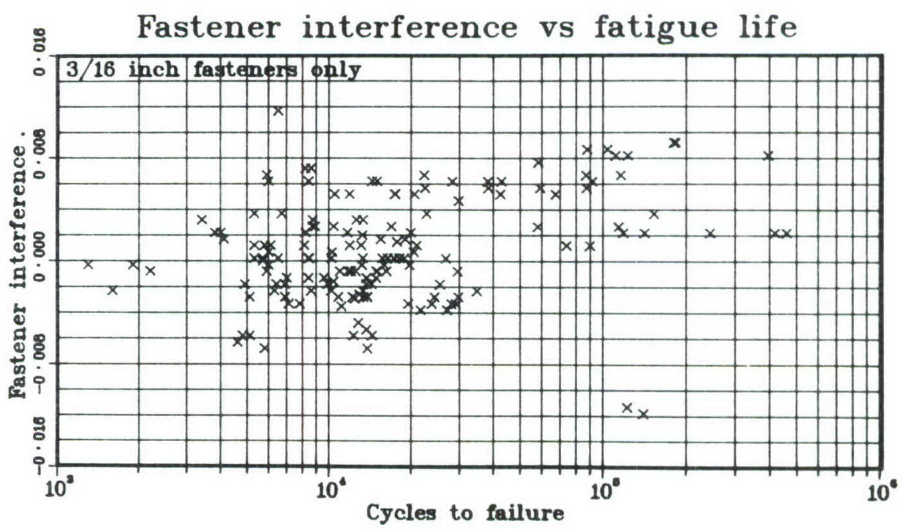

Figure 110. Fastener Interference vs. Fatigue Life for 3/16-Inch Fasteners Only

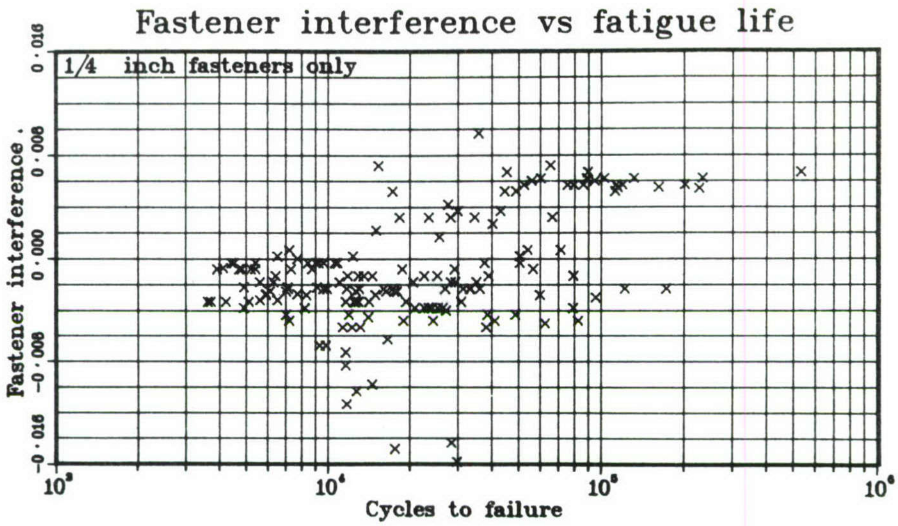

Figure 111. Fastener Interference vs. Fatigue Life for 1/4-Inch Fasteners Only

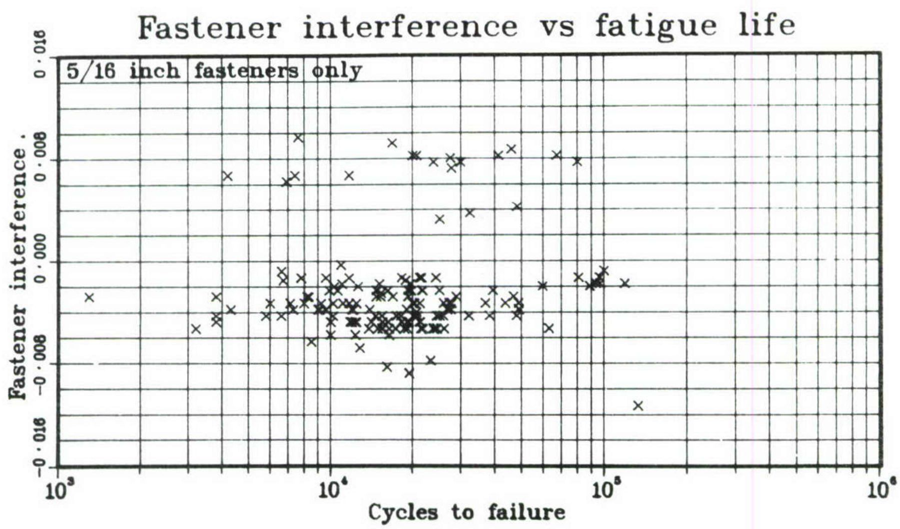

Figure 112. Fastener Interference vs. Fatigue Life for 5/16-Inch Fasteners Only

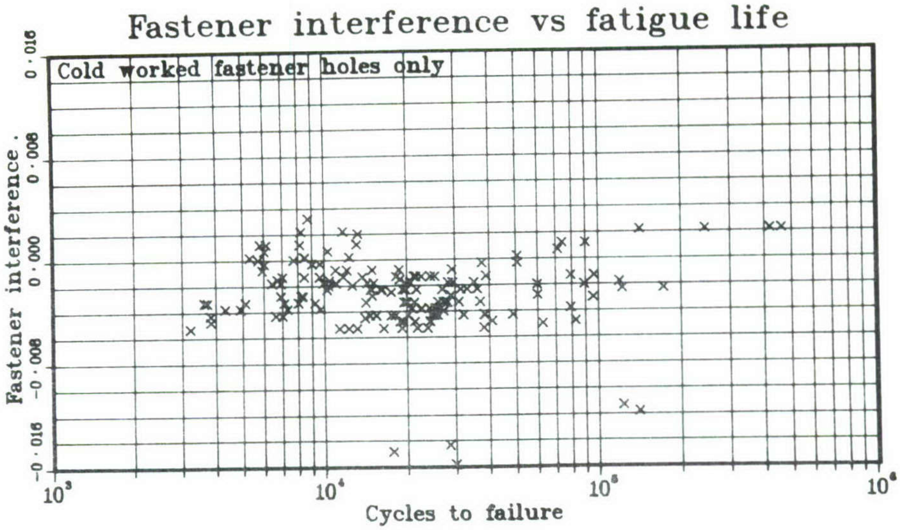

Figure 113. Fastener Interference vs. Fatigue Life for Cold-Worked Fastener Holes Only

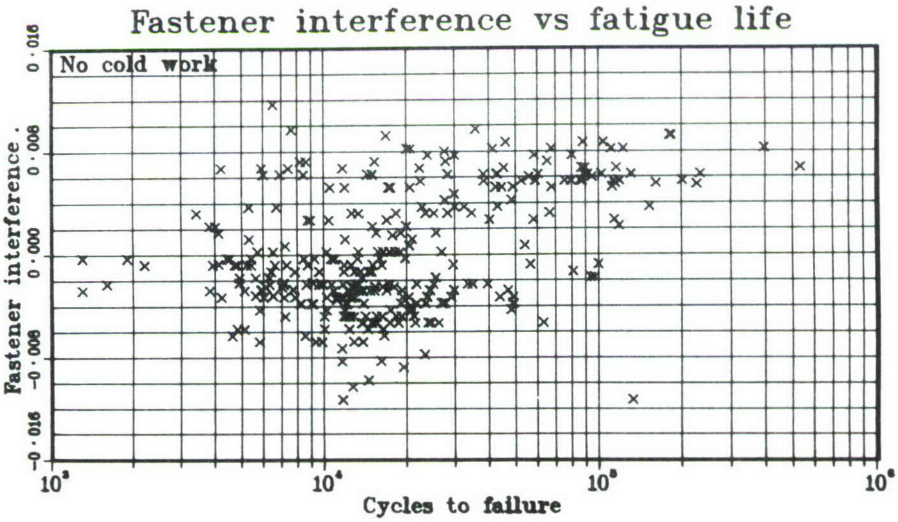

Figure 114. Fastener Interference vs. Fatigue Life for No Cold-Work

removal or subtracted in the case of a specimen where fastener removal occurred. Fastener removal does cause a significant shortening of the fatigue life of most specimens.

As a result of an oversight in the handling and testing of the specimens, several of the specimens scheduled for fastener removal were tested without fastener removal. After this oversight was discovered, the specimens scheduled for fastener removal were segregated, and they were marked to prevent the situation from recurring.

n. Fastener Shank Contact

As previously mentioned, the fastener shank contact could only be determined after failure by examining the fastener and hole. As would be expected from knowledge of other fatigue life enhancing fastener systems, the longer-lived specimens showed more shank contact. Shank contact effects are illustrated in Figures 115 through 126.

The fastener shank contact was a percentage value and since there is no tool available for determining the contact in straight holes prior to fastener installation, the after-failure information which was obtained makes this less useful than the blue pin, air gage, or capacitance gage techniques which are available for use on Taper-Lok holes. The development of an economical straight hole inspection system would be of considerable use in this regard.

o. Countersink Depth/Sheet Thickness Ratio

This ratio of the depth of the countersink to the thickness of the sheet in which it is placed showed clearly that the deeper the countersink, the lower the expected fatigue life. Examination of the residuals leads to the conclusion that a simple linear function is adequate to describe the behavior of the fatigue life in response to this variable, when it is in the range less than 1., rather than the sigmoidal function suggested by Spaulding (Reference 68). The plots of this factor are in Figures 127 through 138.

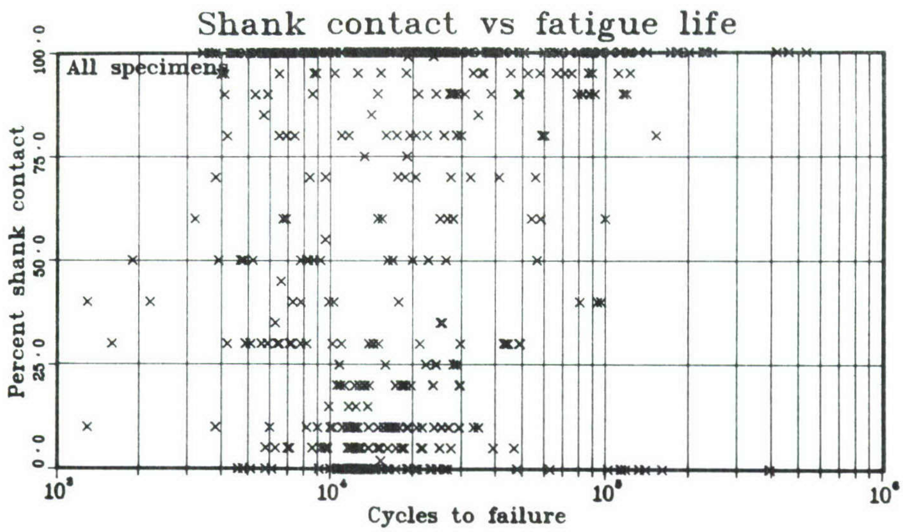

Figure 115. Shank Contact vs. Fatigue Life for All Specimens

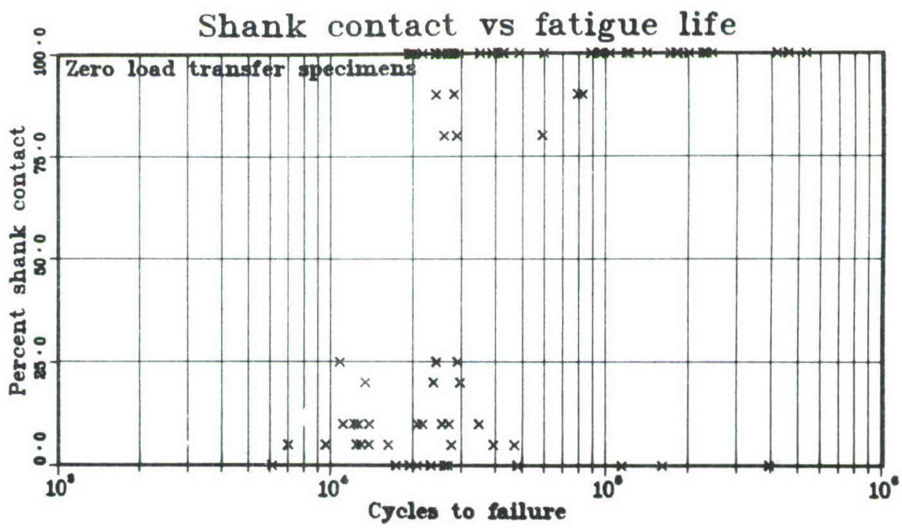

Figure 116. Shank Contact vs. Fatigue Life for Zero Load Transfer Specimens

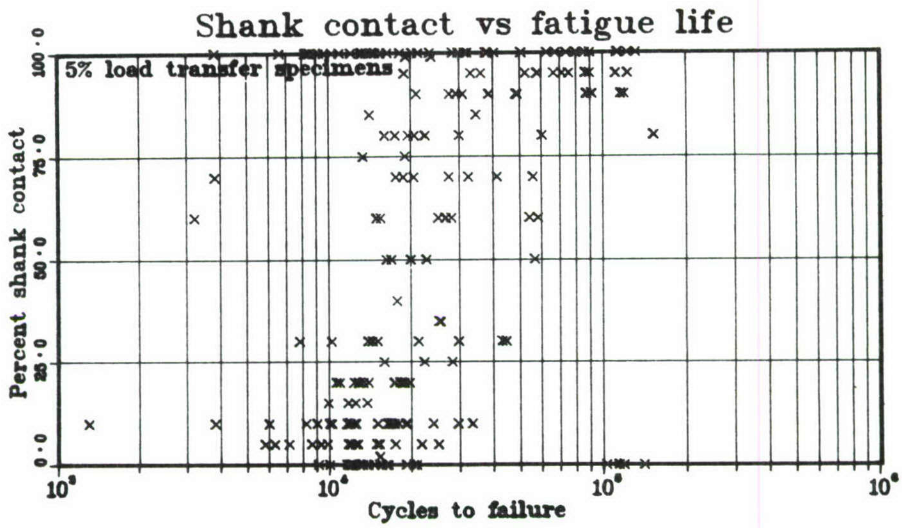

Figure 117. Shank Contact vs. Fatigue Life for 5% Load Transfer Specimens

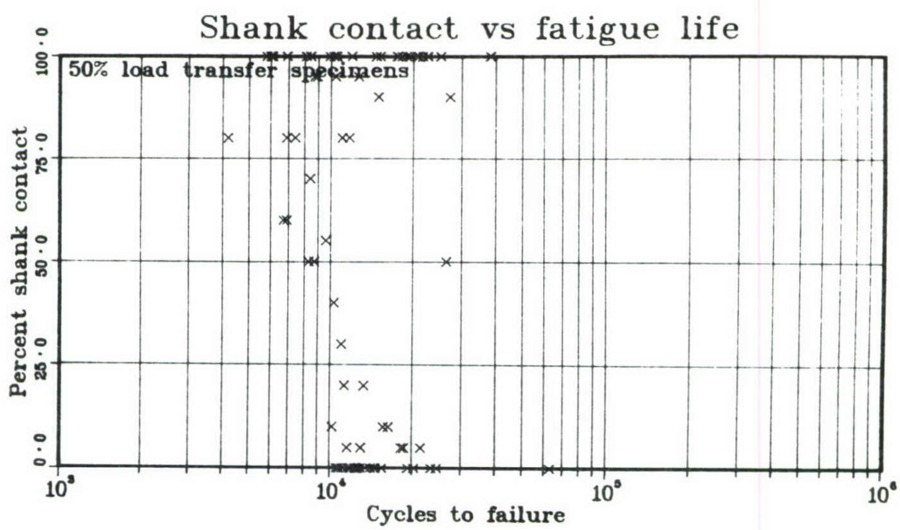

Figure 118. Shank Contact vs. Fatigue Life for 50% Load Transfer Specimens

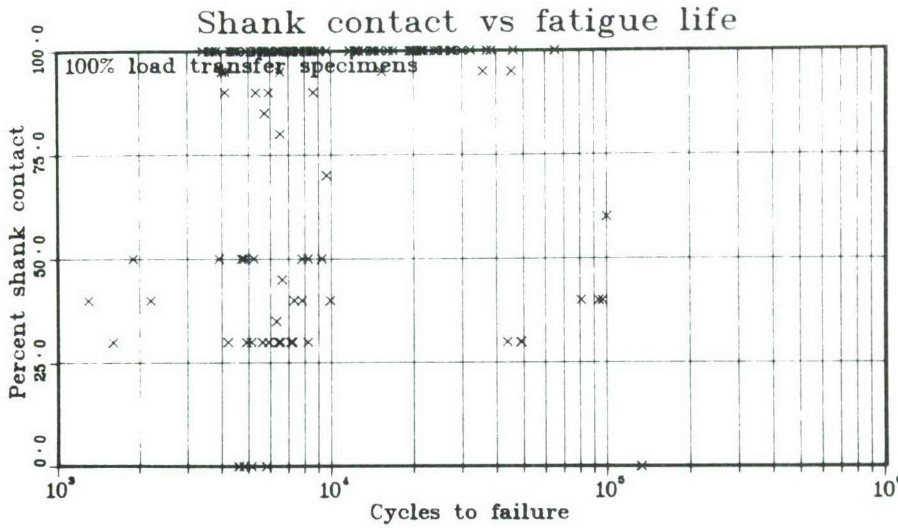

Figure 119. Shank Contact vs. Fatigue Life for 100% Load Transfer Specimens

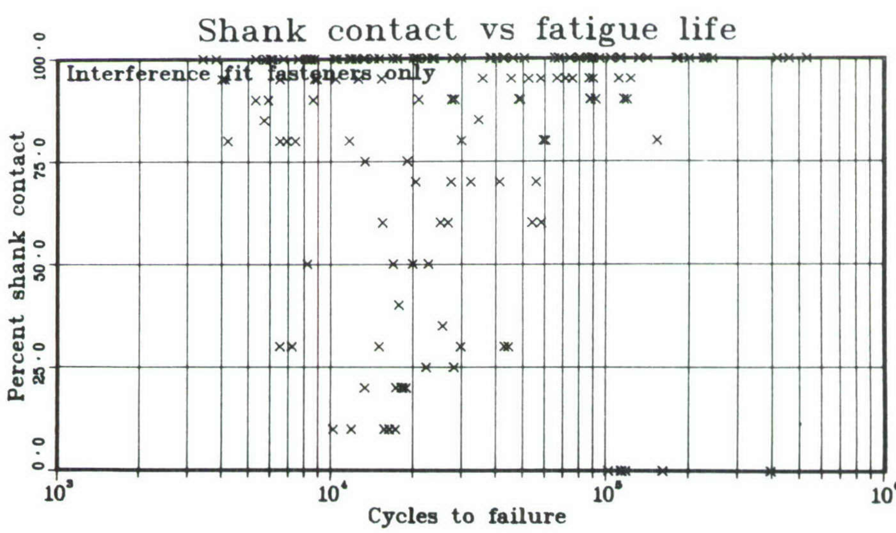

Figure 120. Shank Contact vs. Fatigue Life for Interference Fit Fasteners Only

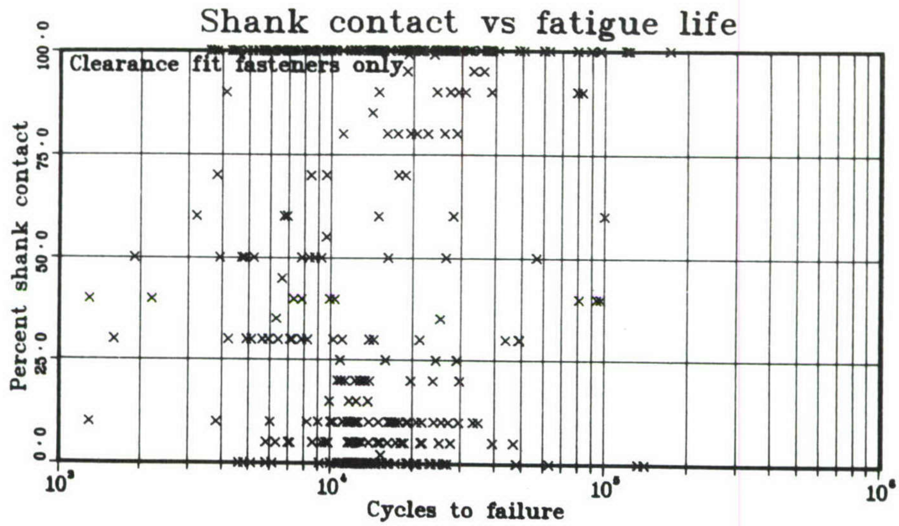

Figure 121. Shank Contact vs. Fatigue Life for Clearance Fit Fasteners Only

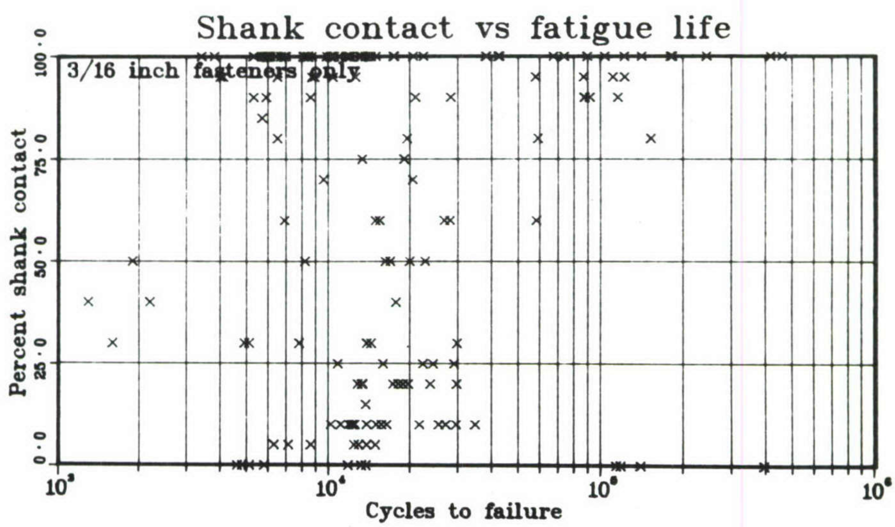

Figure 122. Shank Contact vs. Fatigue Life for 3/16-Inch Fasteners Only

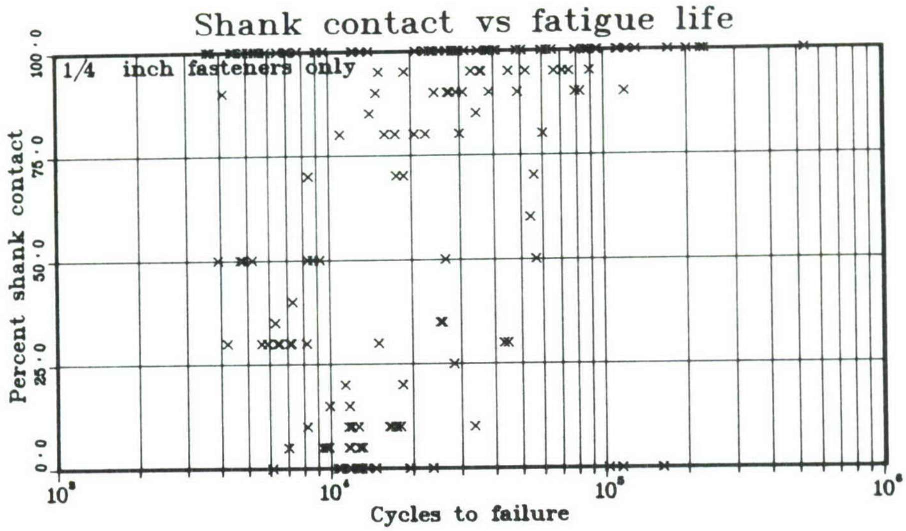

Figure 123. Shank Contact vs. Fatigue Life for 1/4-Inch Fasteners Only

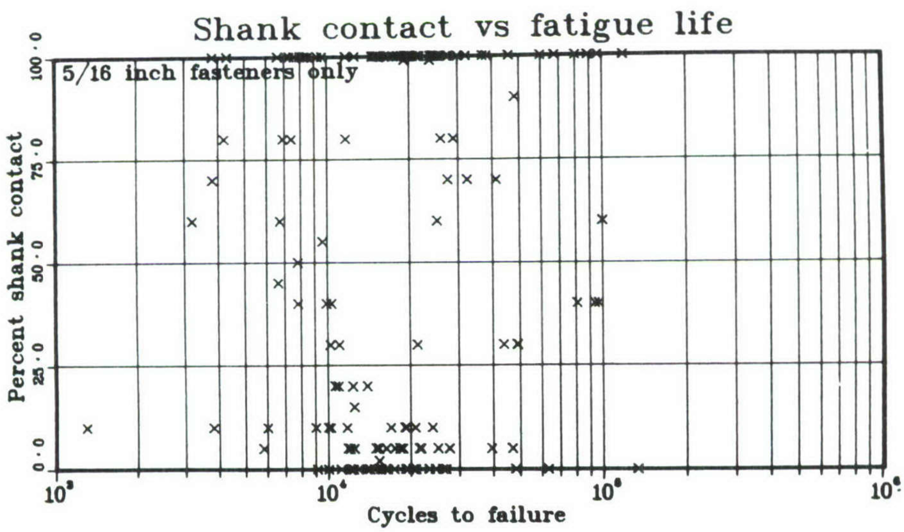

Figure 124. Shank Contact vs. Fatigue Life for 5/16-Inch Fasteners Only

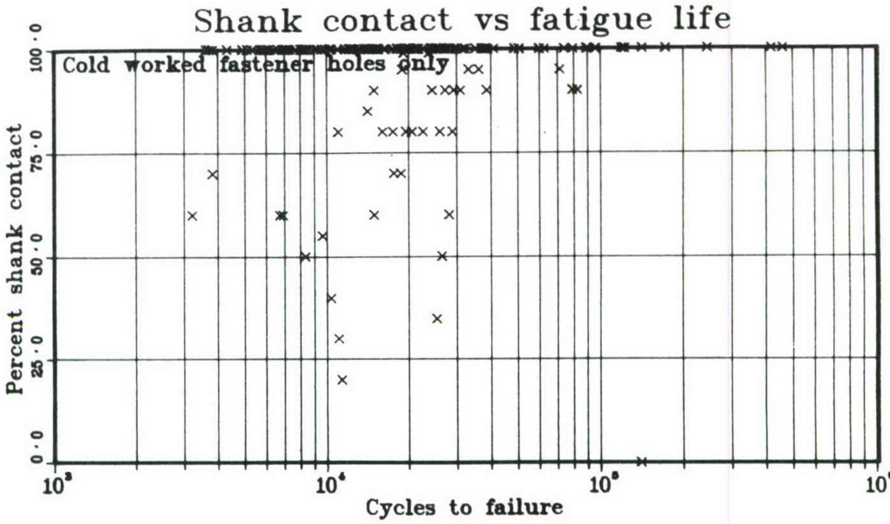

Figure 125. Shank Contact vs. Fatigue Life for Cold-Worked Fastener Holes Only

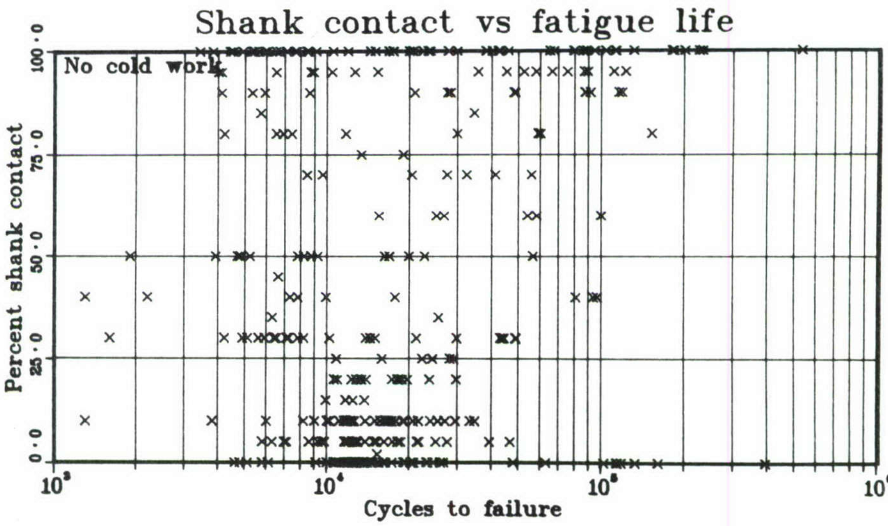

Figure 126. Shank Contact vs. Fatigue Life for No Cold-Work

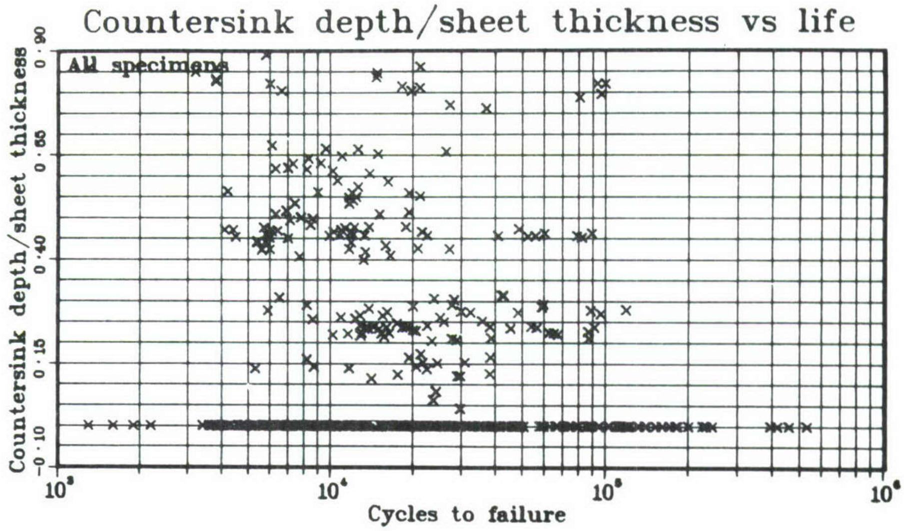

Figure 127. Countersink Depth/Sheet Thickness vs. Fatigue Life for All Specimens

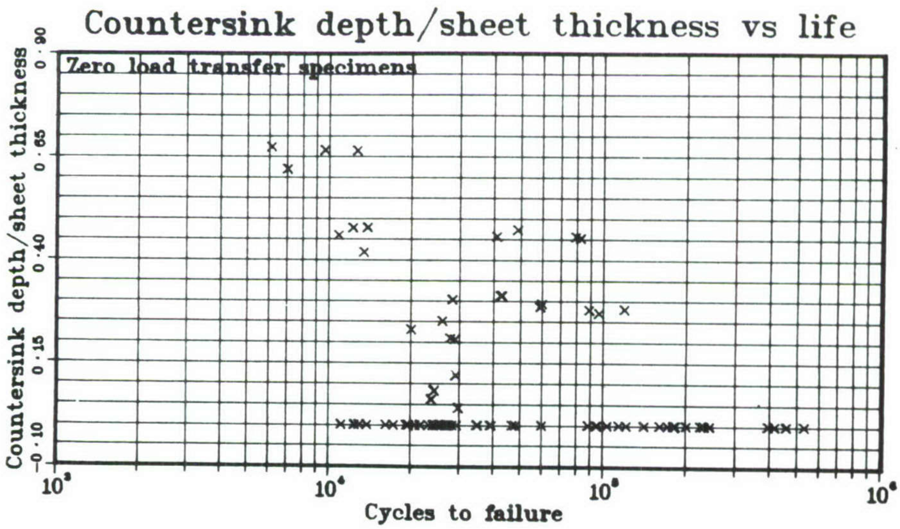

Figure 128. Countersink Depth/Sheet Thickness vs. Fatigue Life for Zero Load Transfer Specimens

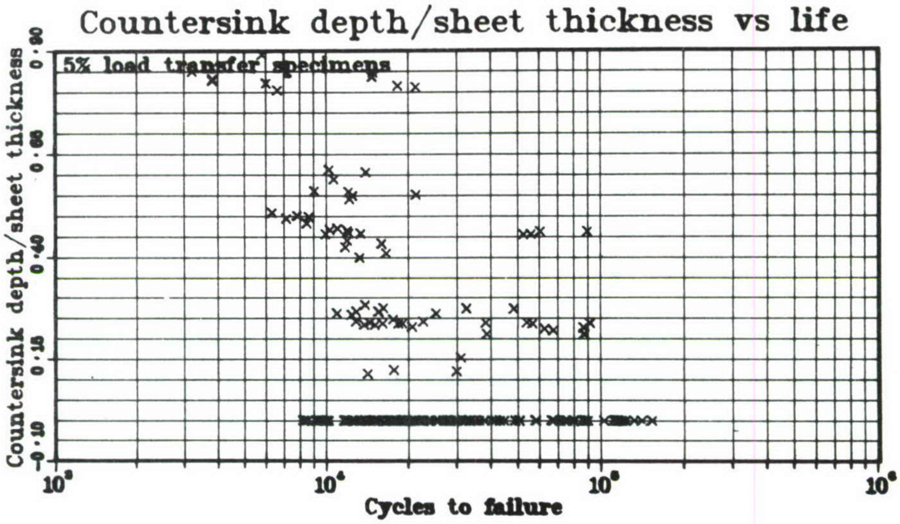

Figure 129. Countersink Depth/Sheet Thickness vs. Fatigue Life for 5% Load Transfer Specimens

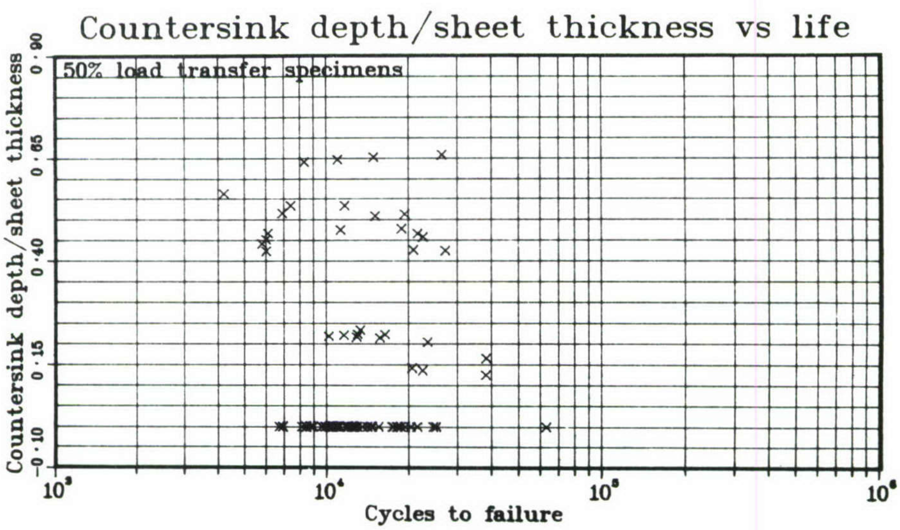

Figure 130. Countersink Depth/Sheet Thickness vs. Fatigue Life for 50% Load Transfer Specimens

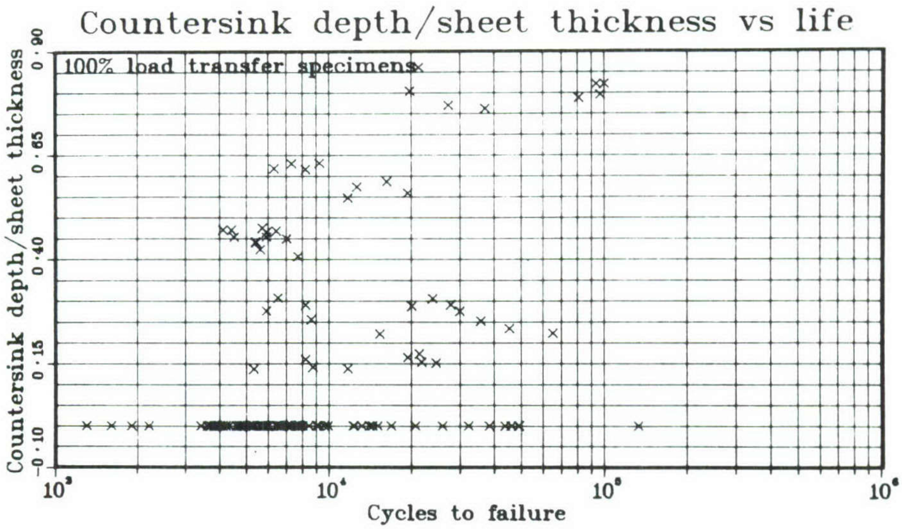

Figure 131. Countersink Depth/Sheet Thickness vs. Fatigue Life for 100% Load Transfer Specimens

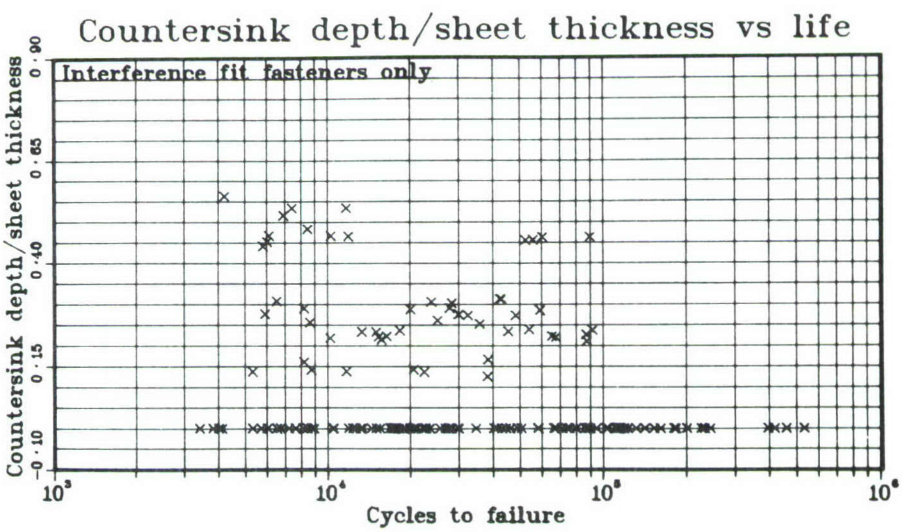

Figure 132. Countersink Depth/Sheet Thickness vs. Fatigue Life for Interference Fit Fasteners Only

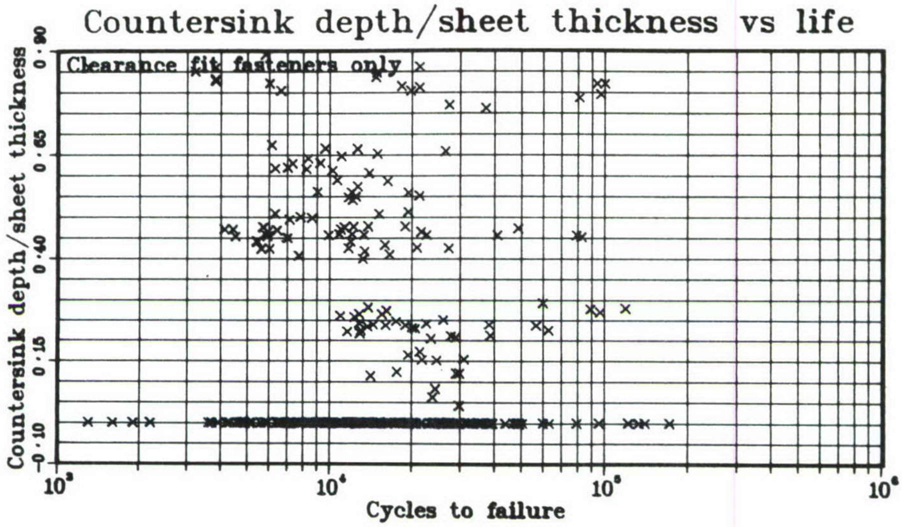

Figure 133. Countersink Depth/Sheet Thickness vs. Fatigue Life for Clearance Fit Fasteners Only

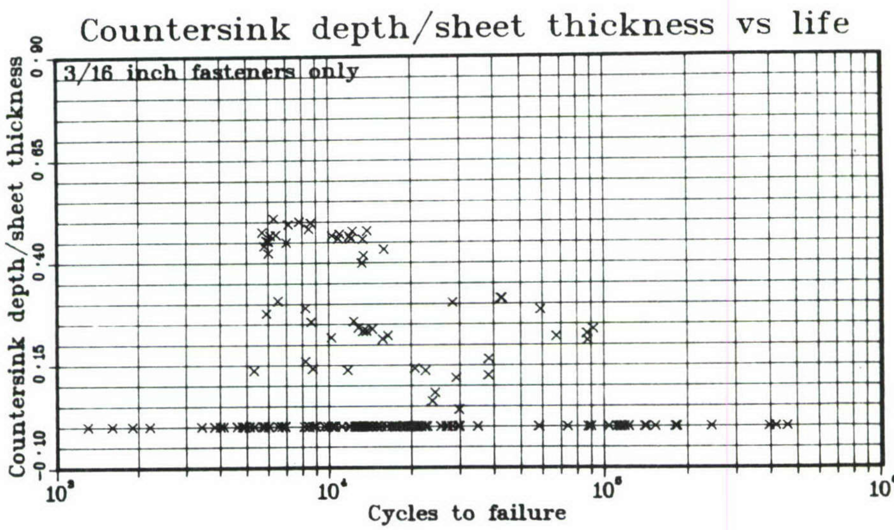

Figure 134. Countersink Depth/Sheet Thickness vs. Fatigue Life for 3/16-Inch Fasteners Only

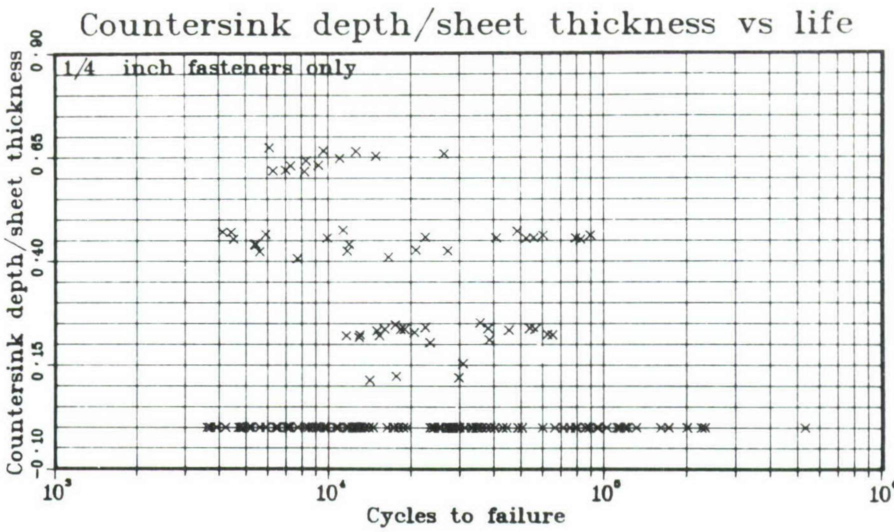

Figure 135. Countersink Depth/Sheet Thickness vs. Fatigue Life for 1/4-Inch Fasteners Only

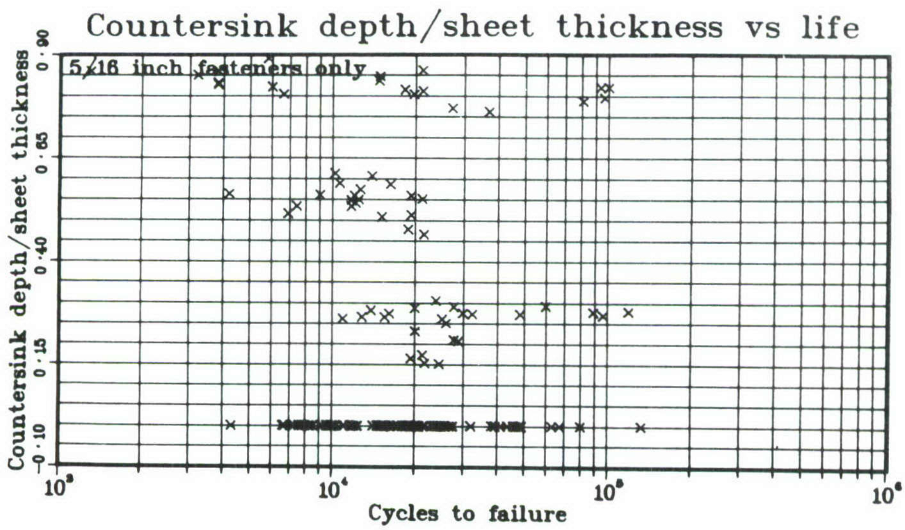

Figure 136. Countersink Depth/Sheet Thickness vs. Fatigue Life for 5/16-Inch Fasteners Only

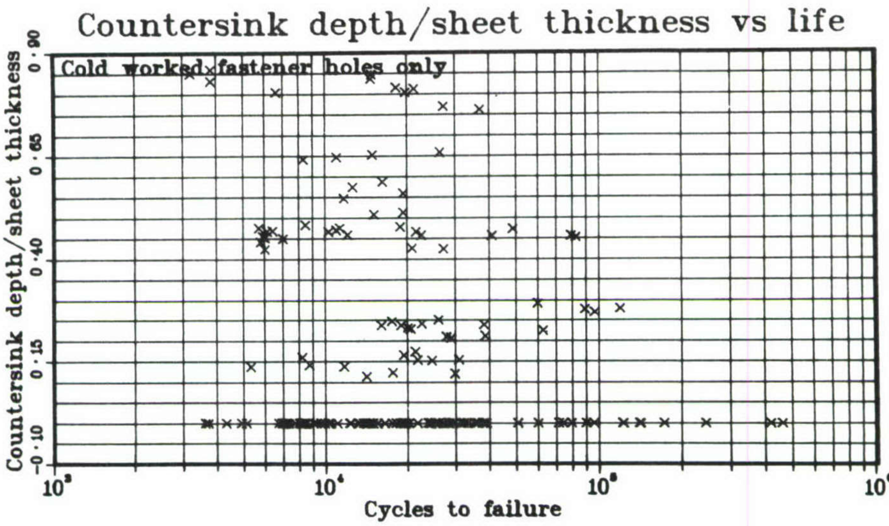

Figure 137. Countersink Depth/Sheet Thickness vs. Fatigue Life for Cold-Worked Fastener Holes Only

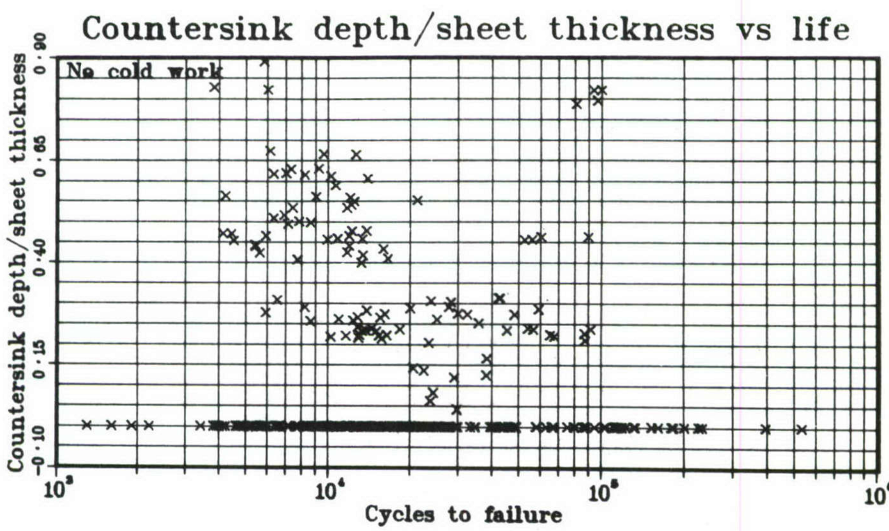

Figure 138. Countersink Depth/Sheet Thickness vs. Fatigue Life for No Cold-Work

p. Test Humidity

The test room relative humidity was recorded for each test and shown in Figures 139 through 150. The apparent relationship between the relative humidity and the fatigue life is somewhat surprising, particularly in view of the conclusion reached by Morris, Buck, and Marcus that relative humidity and fatigue life were "roughly independent" for 2219-T851 (Reference 69).

q. Straightness Difference Between Holes

The difference in straightness, in inches, for the two holes in each specimen was computed and is shown in Figures 151 through 161. This parameter shows that a difference in straightness is likely to lead to shorter fatigue life. It cannot be proven from this experiment, but it seems likely that a difference in straightness between the two holes results in residual stresses in the plates when the fasteners are installed. These residual stresses then lead to earlier crack initiation growth and failure of the specimen.

r. Total Thickness/Fastener Diameter

The total thickness/fastener diameter ratio, or t/d ratio, shows that as this number increases the fatigue life of the specimen decreases. This is shown in Figures 162 through 173.

s. Wet Installation

The wet installation variable was coded in a manner similar to the removal variable; that is, it was set at 1.0, if the fastener was wet installed, and -1.0, if the fastener was put in dry. The results of the regression equations indicate that wet installation of the fasteners reduces slightly the expected fatigue lives of the specimens. This minor penalty in fatigue performance must be judged against the major improvement in corrosion resistance which this provides.

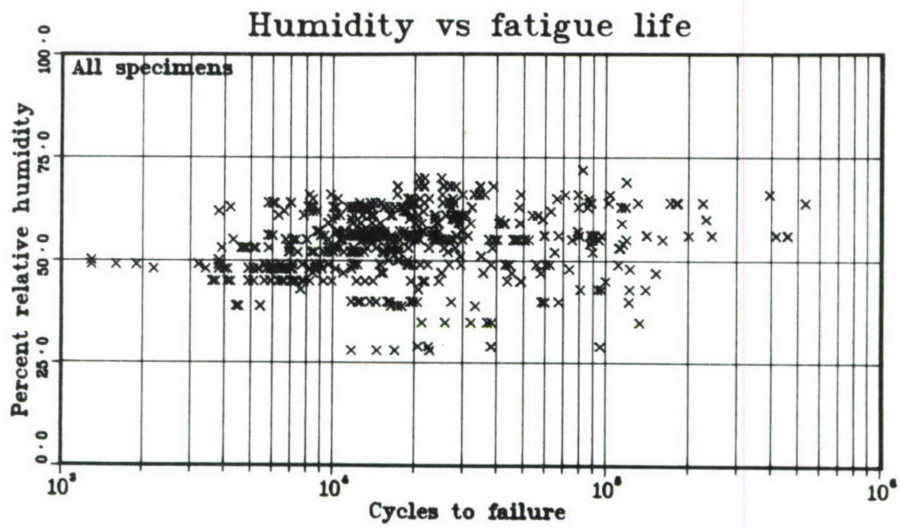

Figure 139. Humidity vs. Fatigue Life for All Specimens

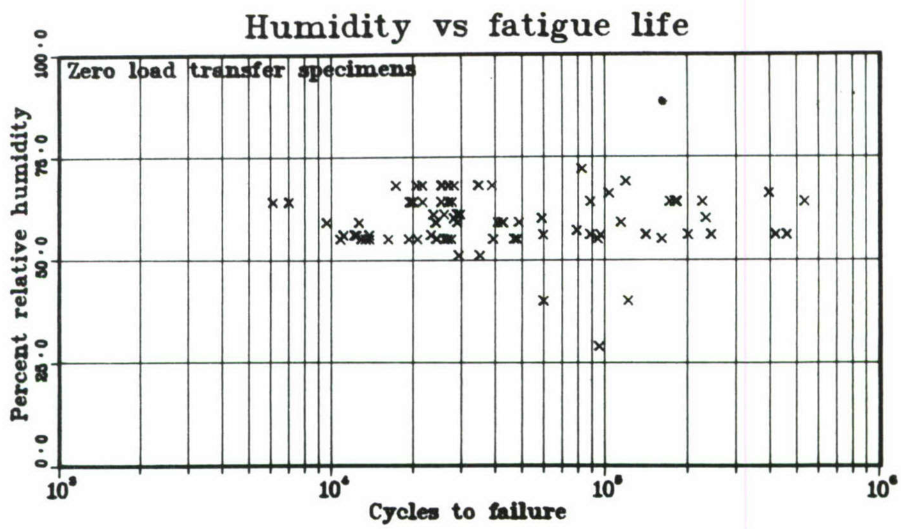

Figure 140. Humidity vs. Fatigue Life for Zero Load Transfer Specimens

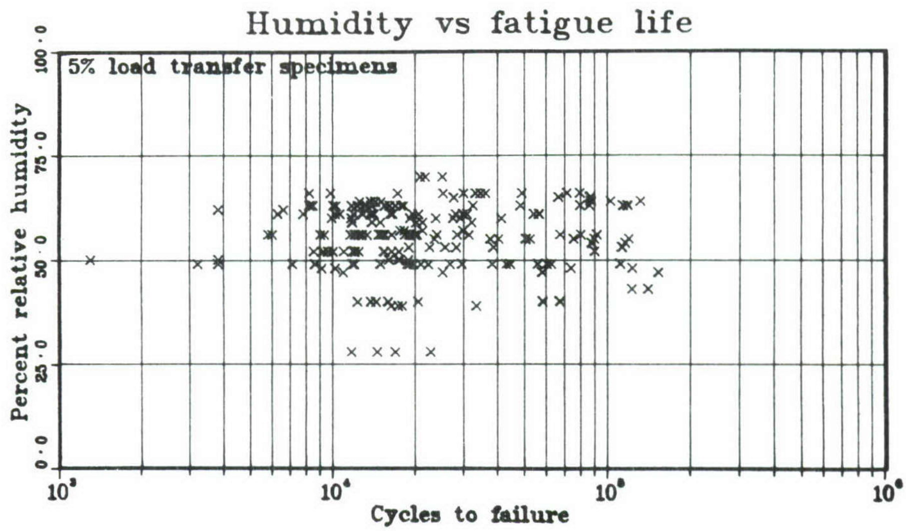

Figure 141. Humidity vs. Fatigue Life for 5% Load Transfer Specimens

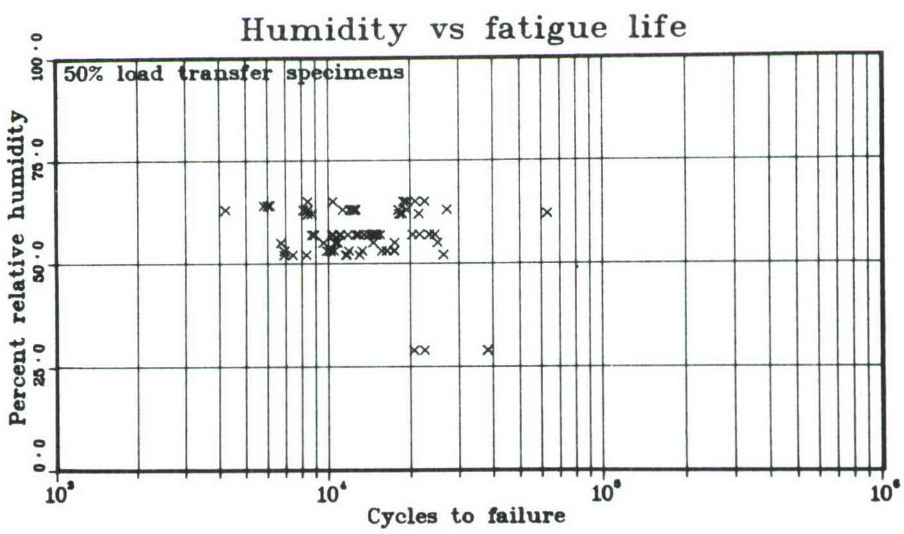

Figure 142. Humidity vs. Fatigue Life for 50% Load Transfer Specimens

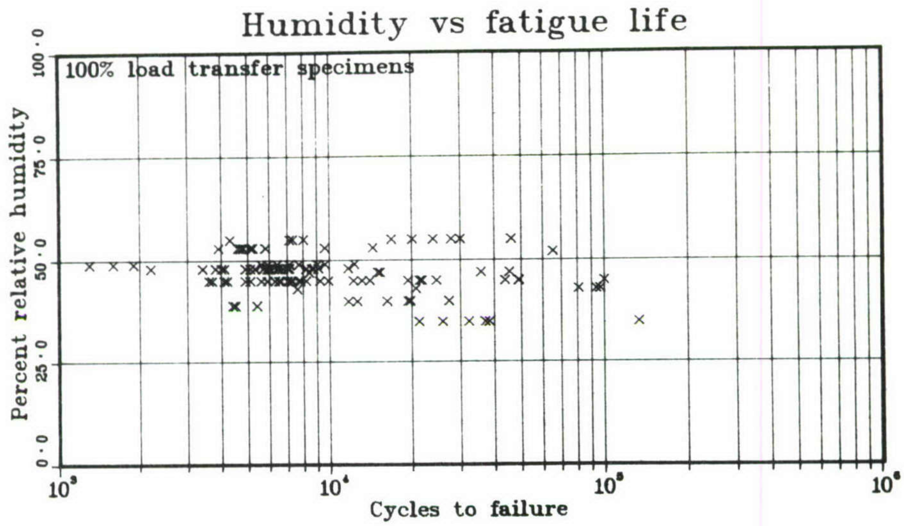

Figure 143. Humidity vs. Fatigue Life for 100% Load Transfer Specimens

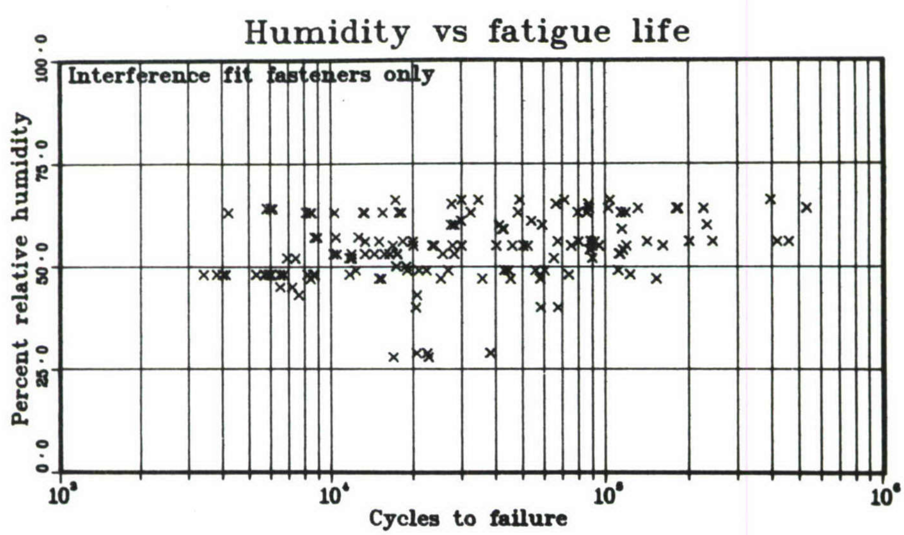

Figure 144. Humidity vs. Fatigue Life for Interference Fit Fasteners Only

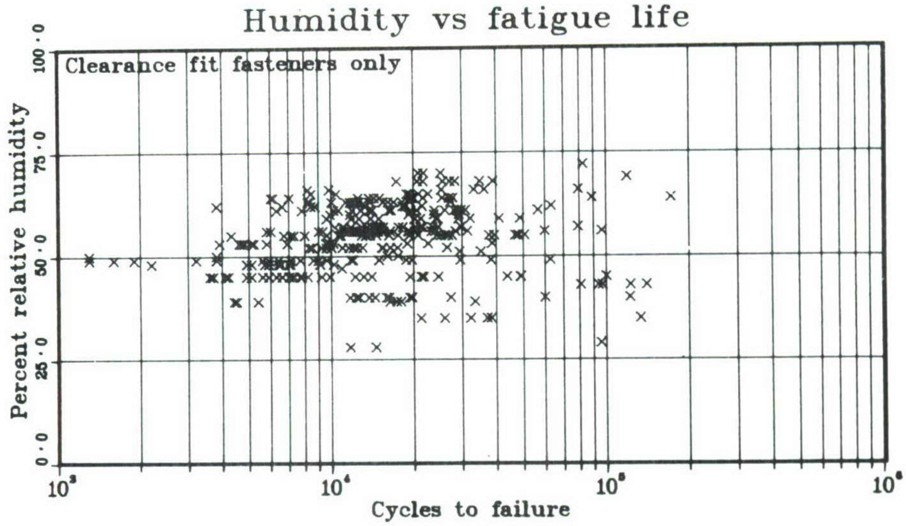

Figure 145. Humidity vs. Fatigue Life for Clearance Fit Fasteners Only

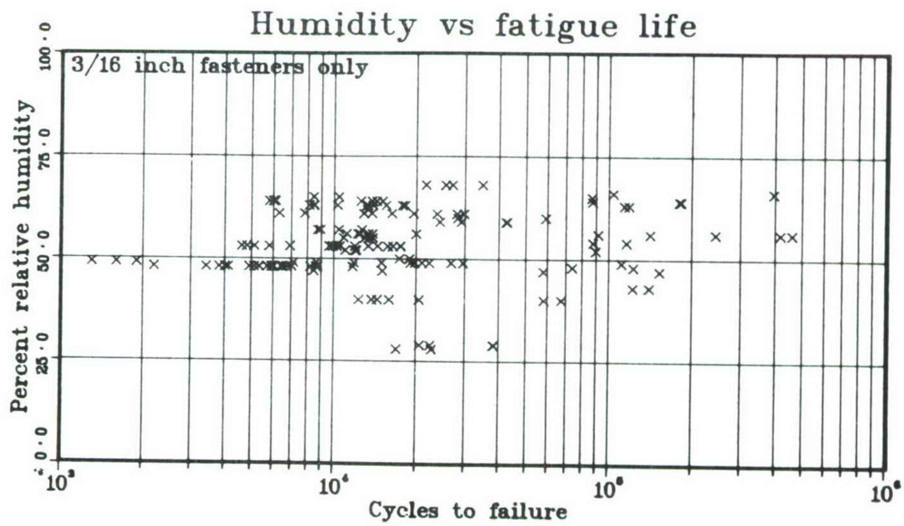

Figure 146. Humidity vs. Fatigue Life for 3/16-Inch Fasteners Only

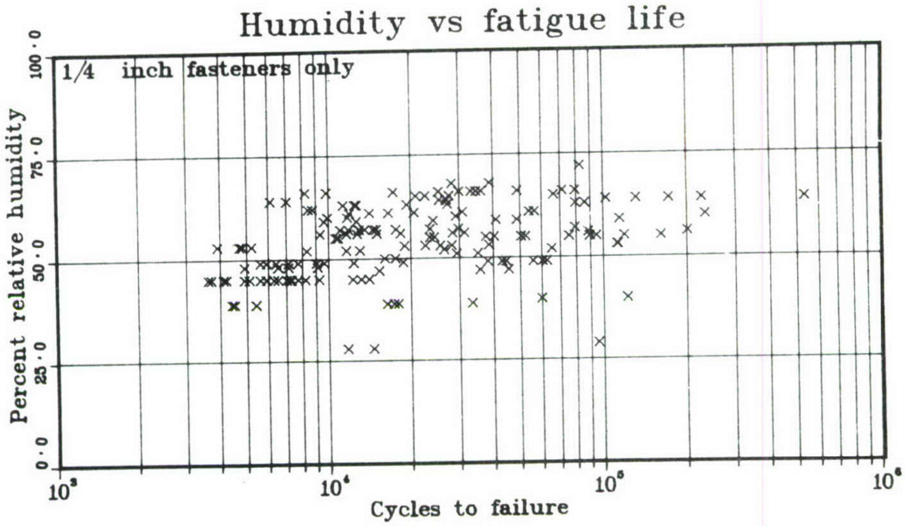

Figure 147. Humidity vs. Fatigue Life for 1/4-Inch Fasteners Only

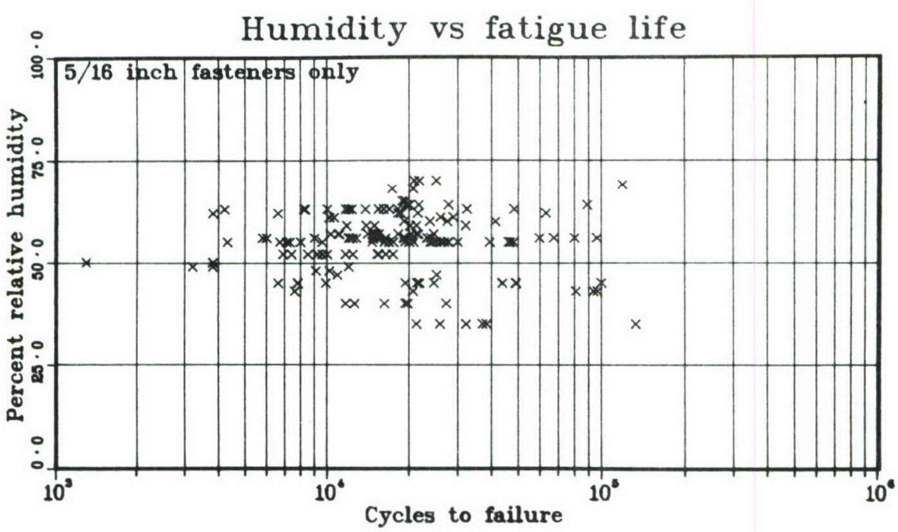

Figure 148. Humidity vs. Fatigue Life for 5/16-Inch Fasteners Only

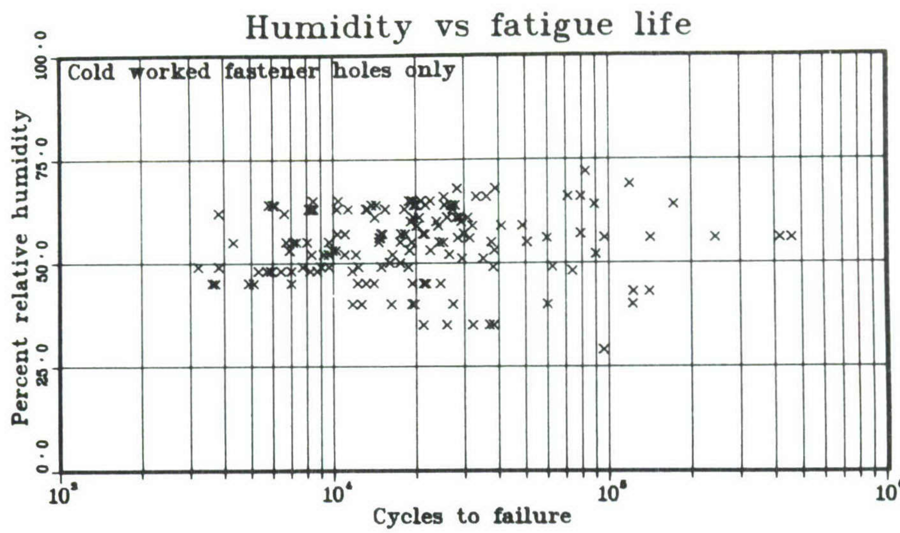

Figure 149. Humidity vs. Fatigue Life for Cold-Worked Fastener Holes Only

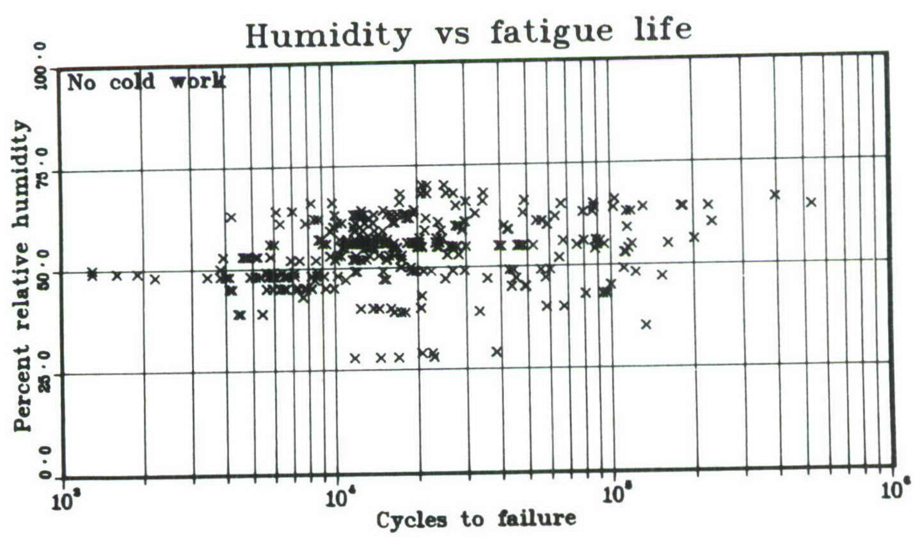

Figure 150. Humidity vs. Fatigue Life for No Cold-Work

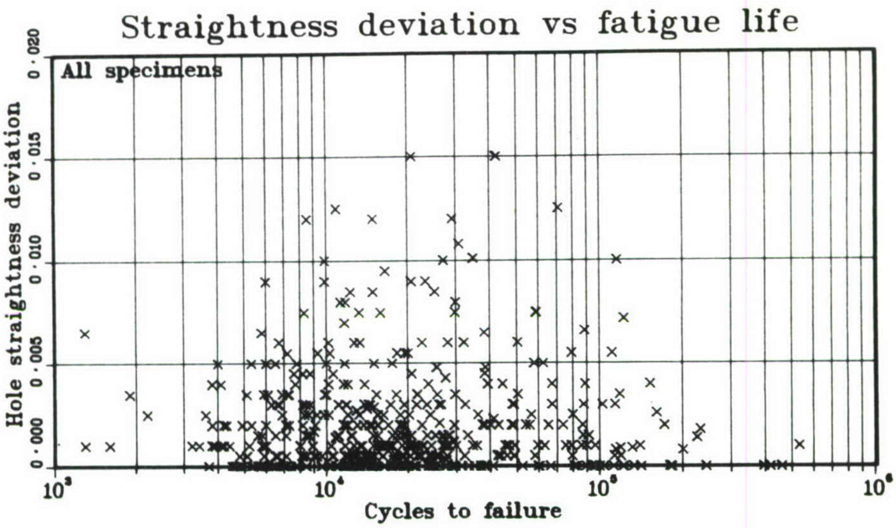

Figure 151. Straightness Deviation vs. Fatigue Life for All Specimens

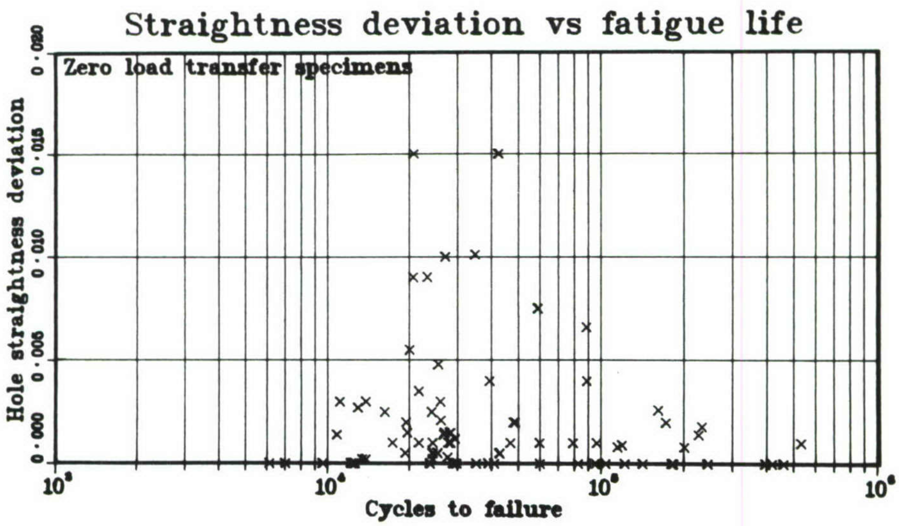

Figure 152. Straightness Deviation vs. Fatigue Life for Zero Load Transfer Specimens

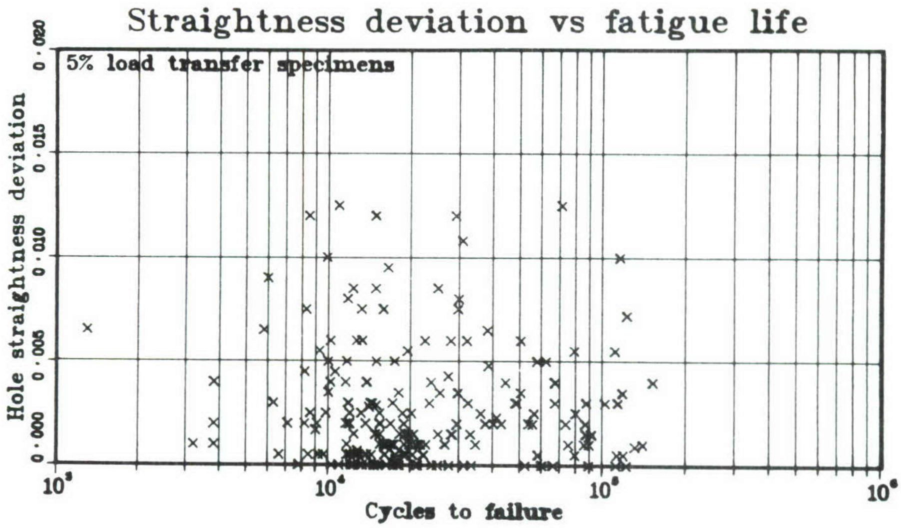

Figure 153. Straightness Deviation vs. Fatigue Life for 5% Load Transfer Specimens

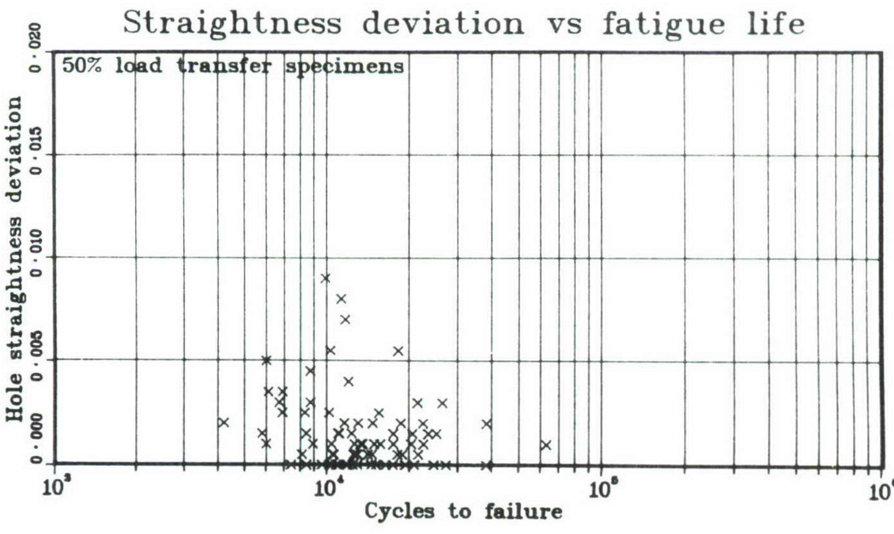

Figure 154. Straightness Deviation vs. Fatigue Life for 50% Load Transfer Specimens

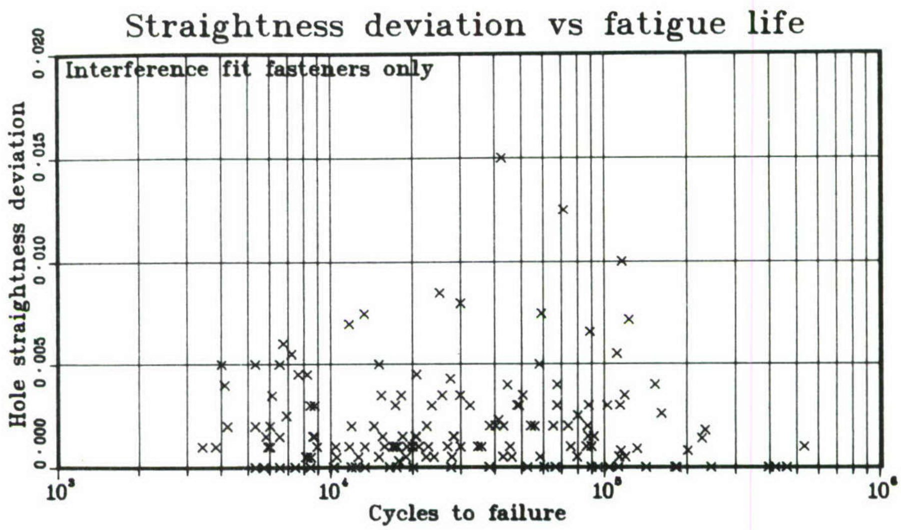

Figure 155. Straightness Deviation vs. Fatigue Life for Interference Fit Fasteners Only

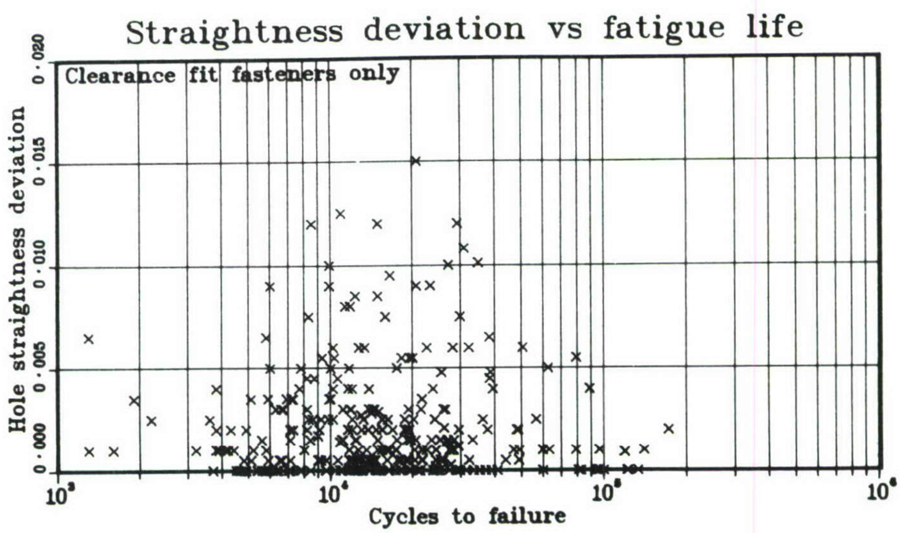

Figure 156. Straightness Deviation vs. Fatigue Life for Clearance Fit Fasteners Only

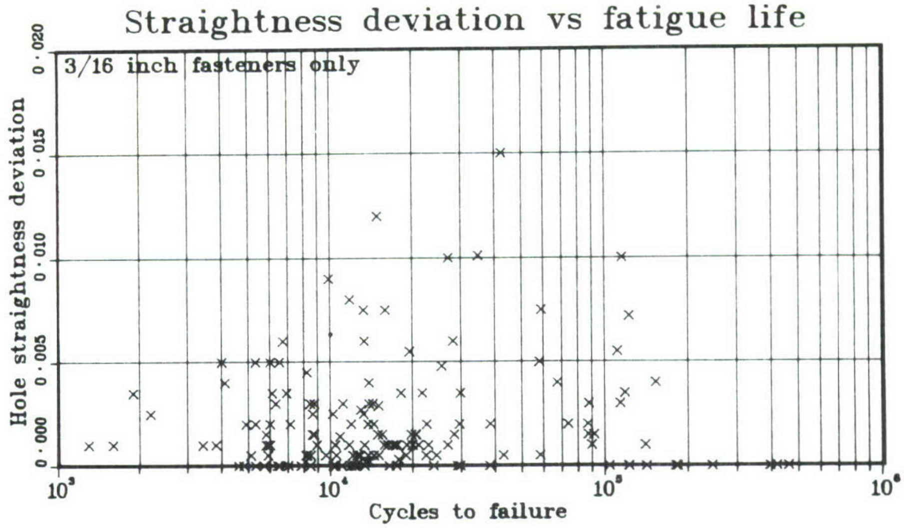

Figure 157. Straightness Deviation vs. Fatigue Life for 3/16-Inch Fasteners Only

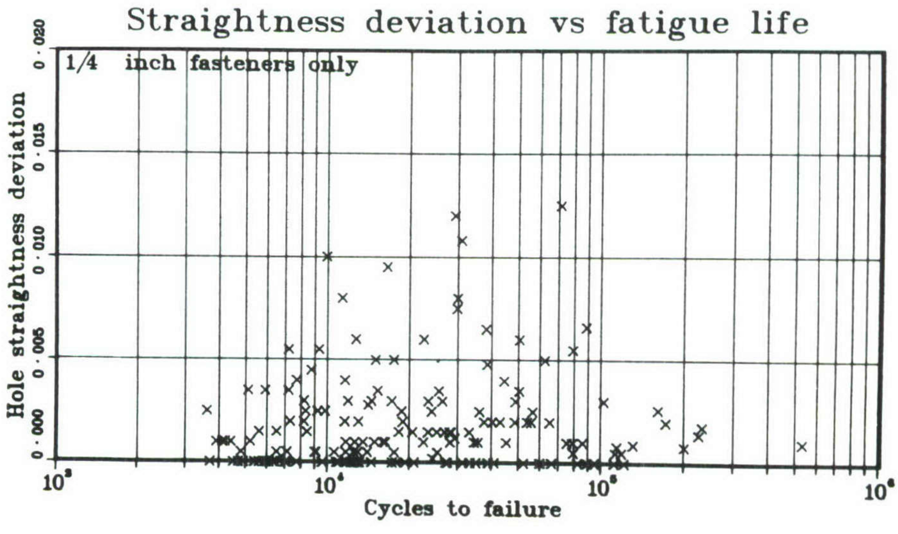

Figure 158. Straightness Deviation vs. Fatigue Life for 1/4-Inch Fasteners Only

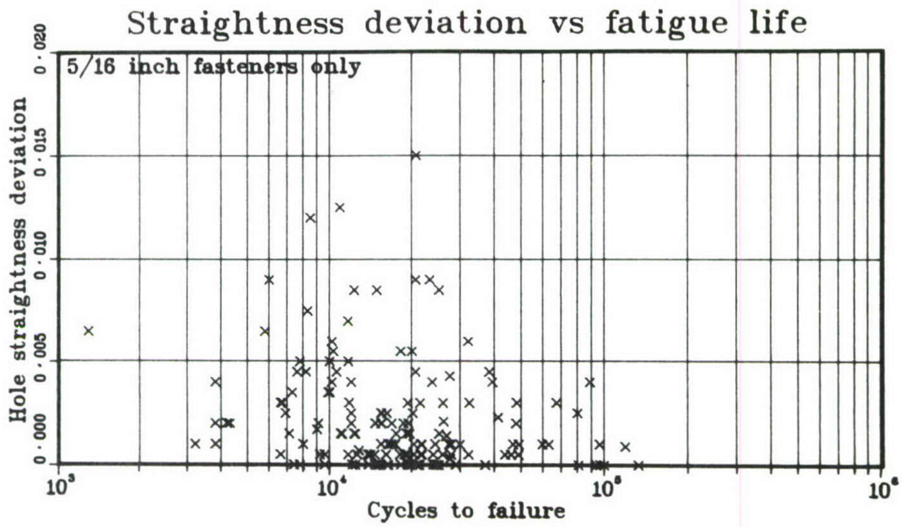

Figure 159. Straightness Deviation vs. Fatigue Life for 5/16-Inch Fasteners Only

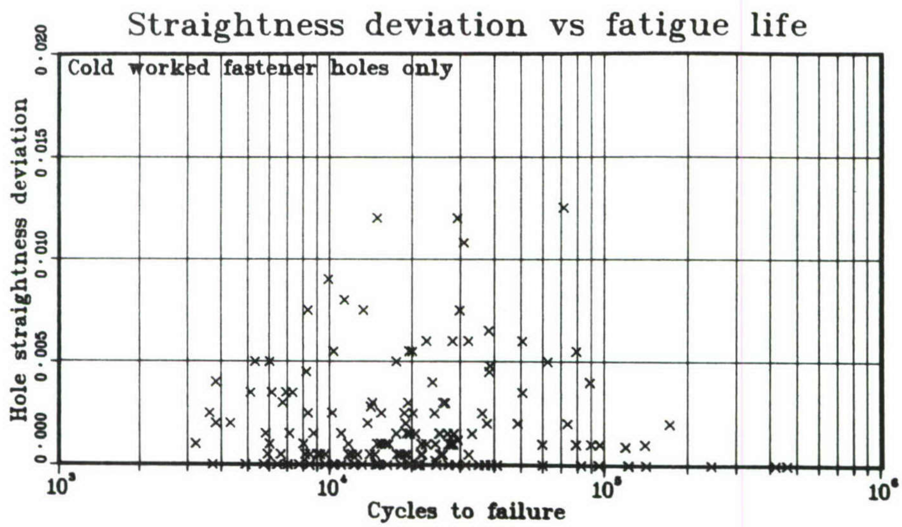

Figure 160. Straightness Deviation vs. Fatigue Life for Cold-Worked Fastener Holes Only

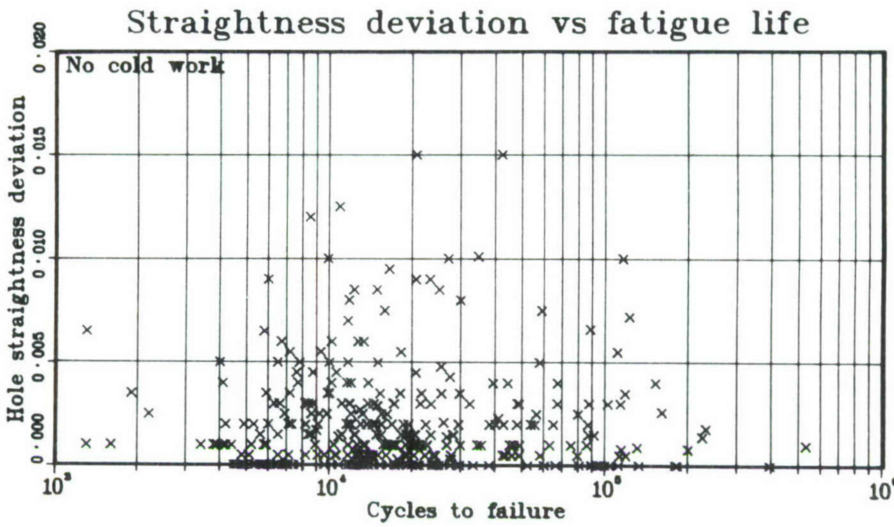

Figure 161. Straightness Deviation vs. Fatigue Life for No Cold-Work

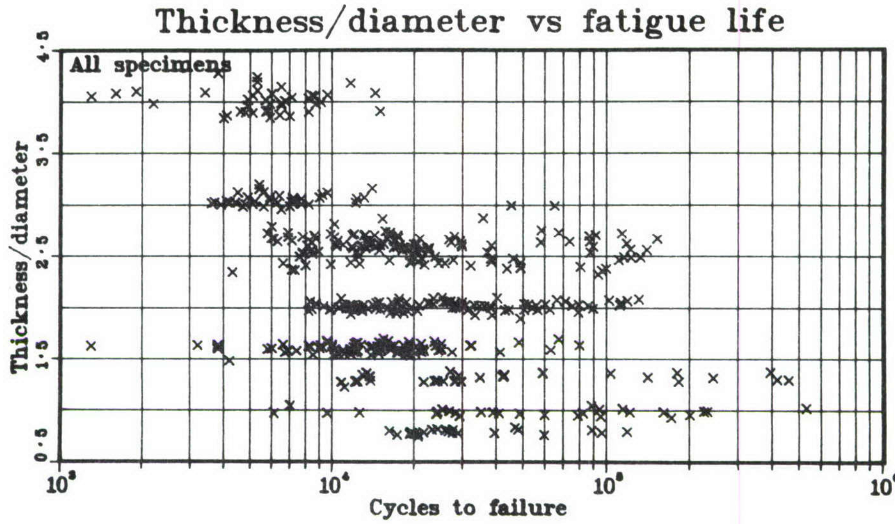

Figure 162. Thickness/Diameter vs. Fatigue Life for All Specimens

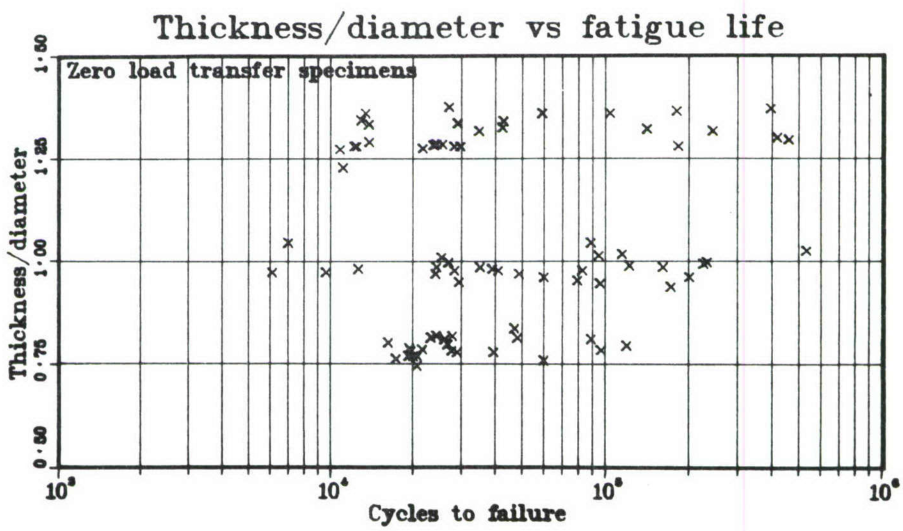

Figure 163. Thickness/Diameter vs. Fatigue Life for Zero Load Transfer Specimens

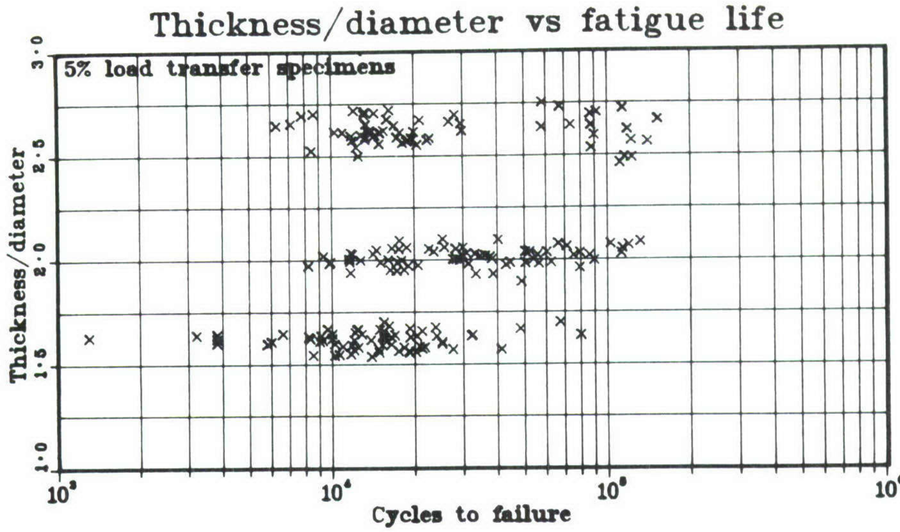

Figure 164. Thickness/Diameter vs. Fatigue Life for 5% Load Transfer Specimens

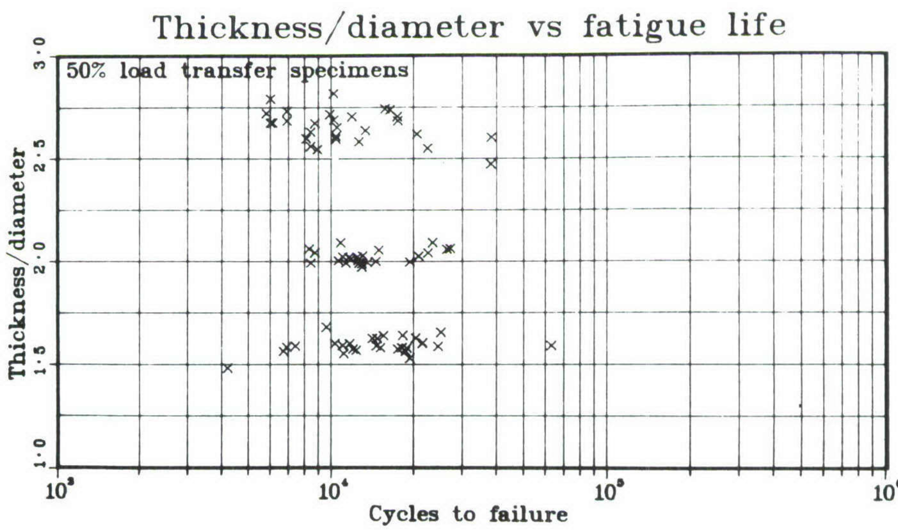

Figure 165. Thickness/Diameter vs. Fatigue Life for 50% Load Transfer Specimens

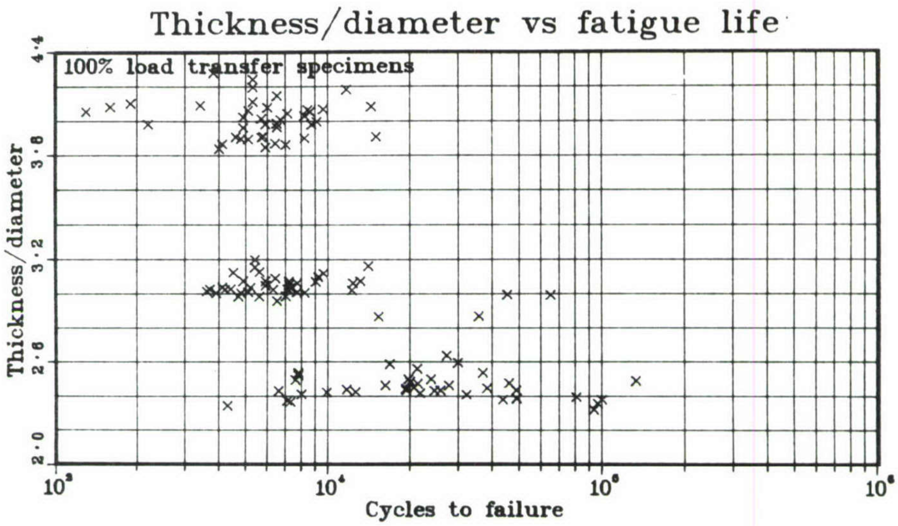

Figure 166. Thickness/Diameter vs. Fatigue Life for 100% Load Transfer Specimens

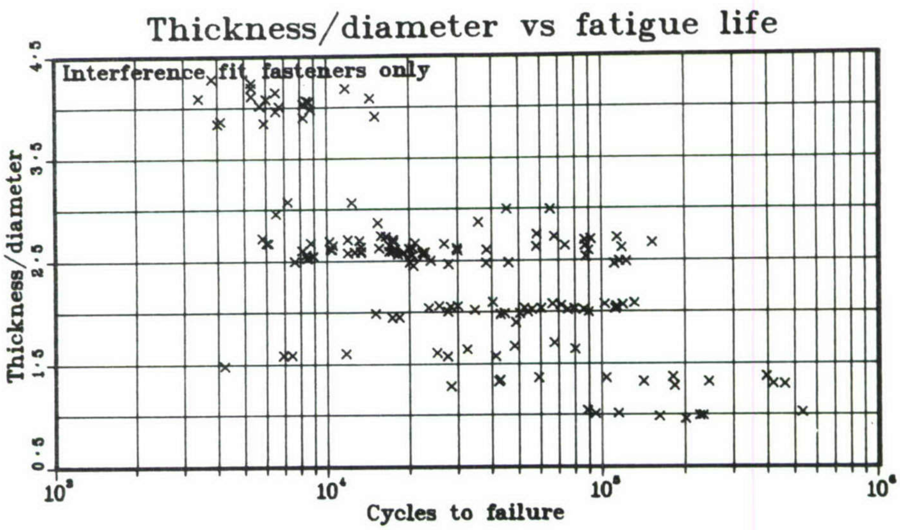

Figure 167. Thickness/Diameter vs. Fatigue Life for Interference Fit Fasteners Only

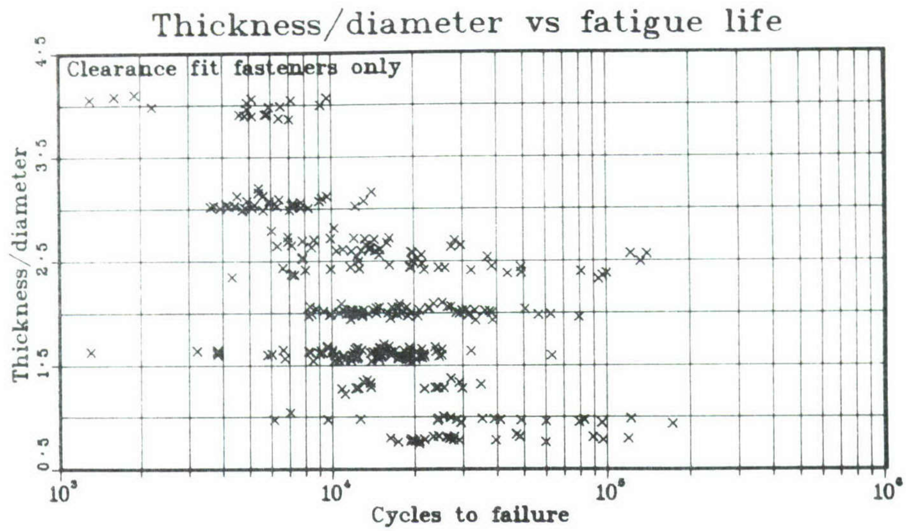

Figure 168. Thickness/Diameter vs. Fatigue Life for Clearance Fit Fasteners Only

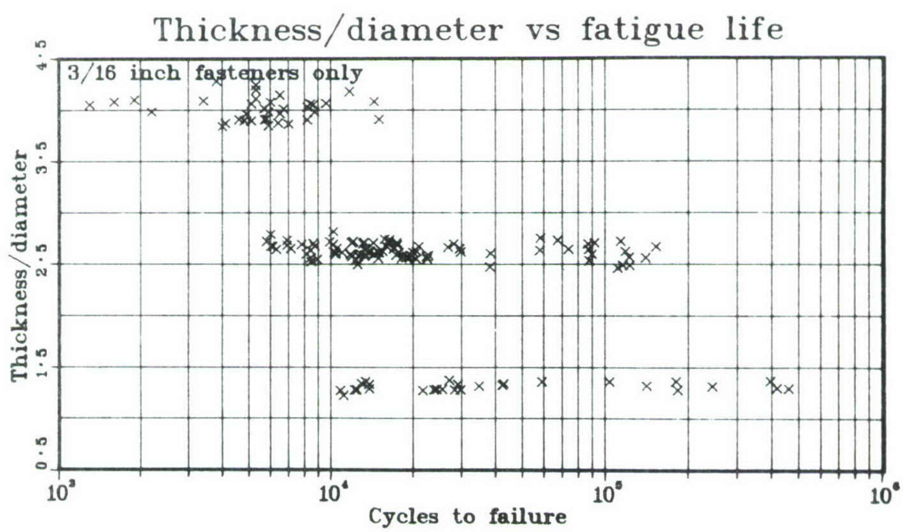

Figure 169. Thickness/Diameter vs. Fatigue Life for 3/16-Inch Fasteners Only

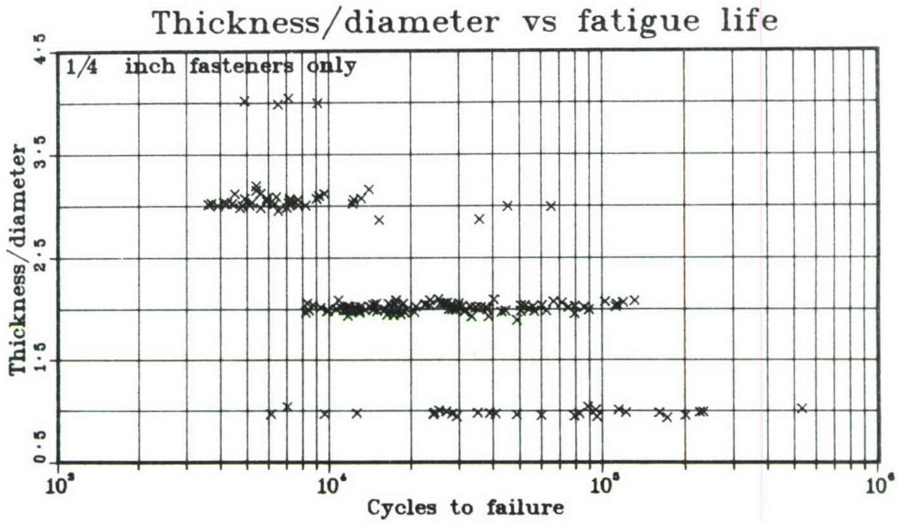

Figure 170. Thickness/Diameter vs. Fatigue Life for 1/4-Inch Fasteners Only

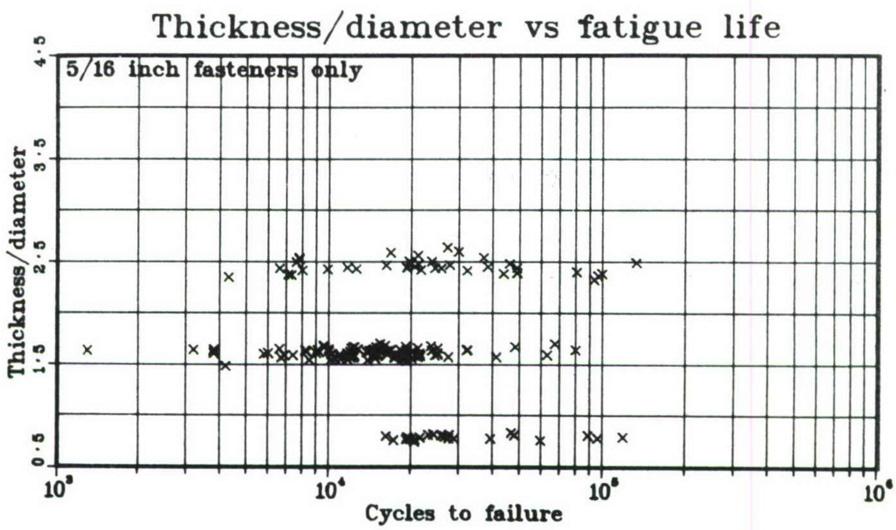

Figure 171. Thickness/Diameter vs. Fatigue Life for 5/16-Inch Fasteners Only

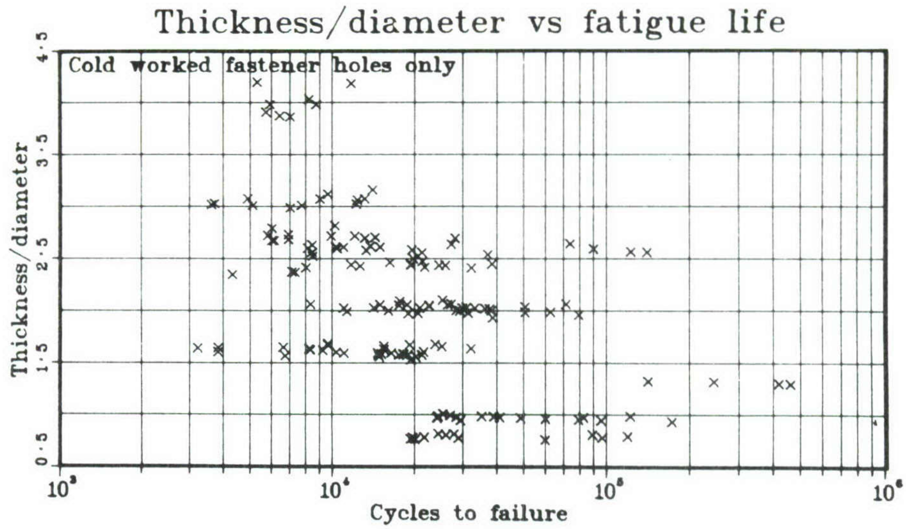

Figure 172. Thickness/Diameter vs. Fatigue Life for Cold-Worked Fastener Holes Only

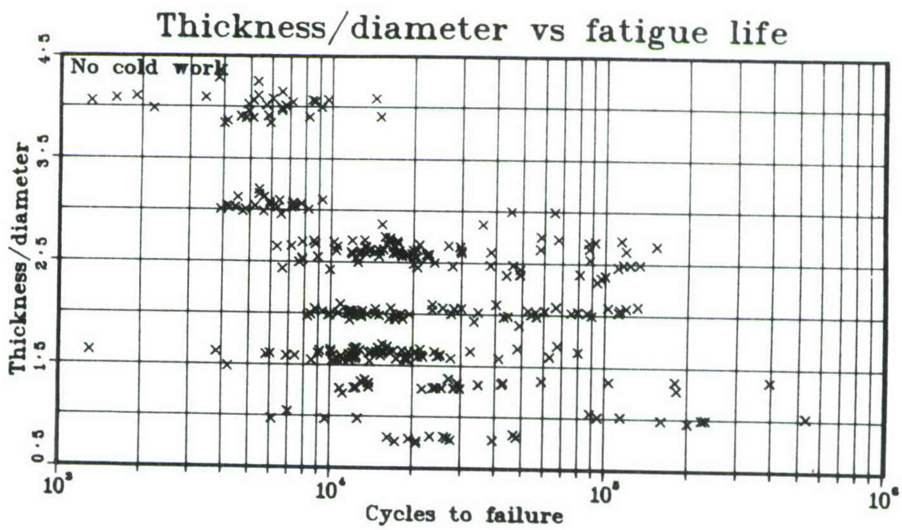

Figure 173. Thickness/Diameter vs. Fatigue Life for No Cold-Work

t. Deburr

In a similar way the deburr parameter has been coded with a 1.0, if the specimen was deburred, and a -1.0, if the specimen was not deburred. Deburring does make a significant difference in the expected fatigue life of the specimen. The abusive hole drilling used on some of the specimens probably produced burrs which are as severe as can be expected and thus served to highlight the problem. However, deburring has been recognized as necessary by many aircraft manufacturers and is commonly done on the production line. Until the means of developing burrless holes becomes routine, deburring will have to continue for fatigue critical structure.

u. Edge Distance/Diameter

The edge distance/diameter, or e/d ratio, did not enter into most of the models, and examination of the edge distances/diameter ratios shows that in the range where the testing took place, this ratio would have little effect on fatigue life. If the edge distance were reduced to less than twice the diameter, a significant change would be expected, and the ratio would be expected to be much more important. The e/d value of 2.0 is commonly used in design manuals (Reference 70) as a minimum value, and the improvement in fatigue life expected from higher values than this is small in comparison to the fatigue life improvement obtained in increasing the e/d value to 2.0.

v. Gap

The gap between sheets is present in only a few of the models, and since the gap is measured in inches, its effect is not a major one in most cases. The effect of the gap would normally be expected to give decreases in fatigue lives, since the gap would allow pin bending and should result in earlier joint failure. Gap effects are shown in Figures 174 through 184.

w. Coining Collars

Coining collars were most effective in zero load transfer specimens. In thicker stack-ups they seemed to have little effect.

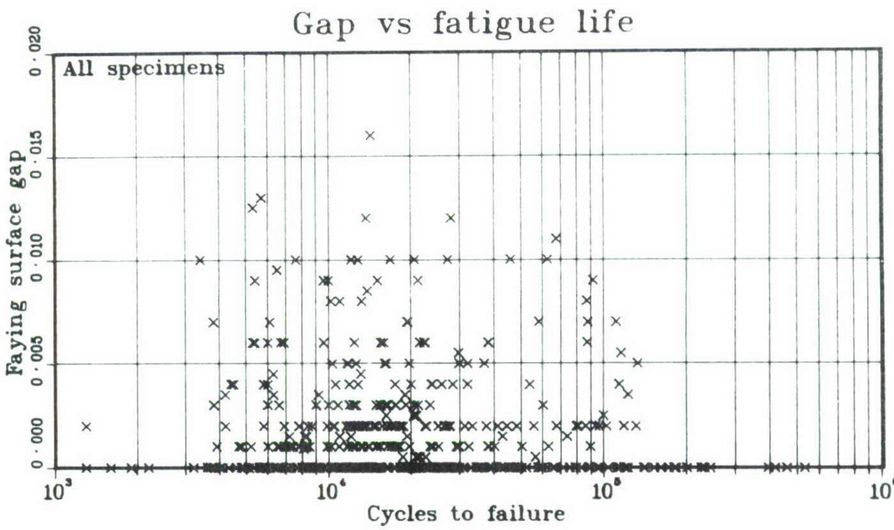

Figure 174. Gap vs. Fatigue Life for All Specimens

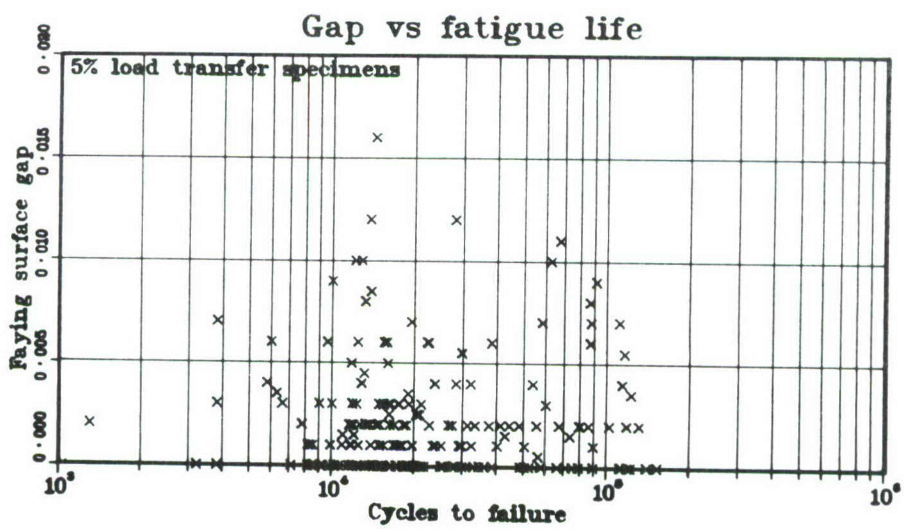

Figure 175. Gap vs. Fatigue Life for 5% Load Transfer Specimens

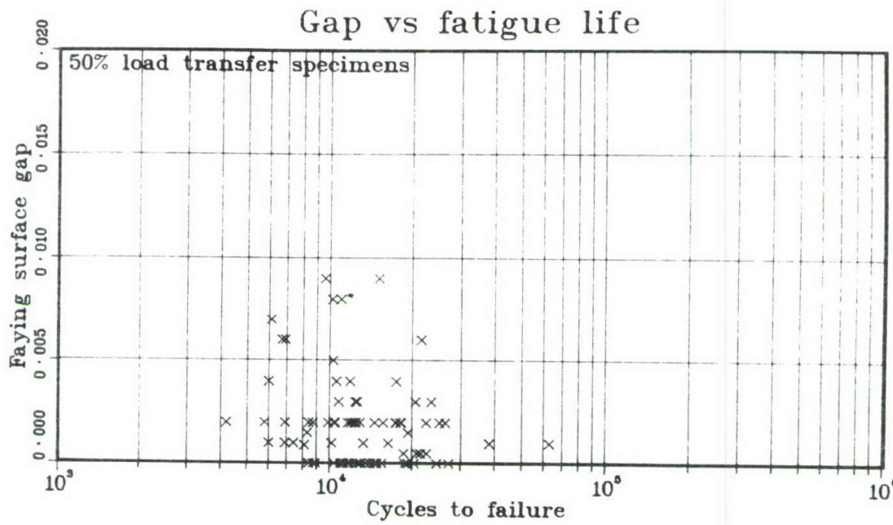

Figure 176. Gap vs. Fatigue Life for 50% Load Transfer Specimens

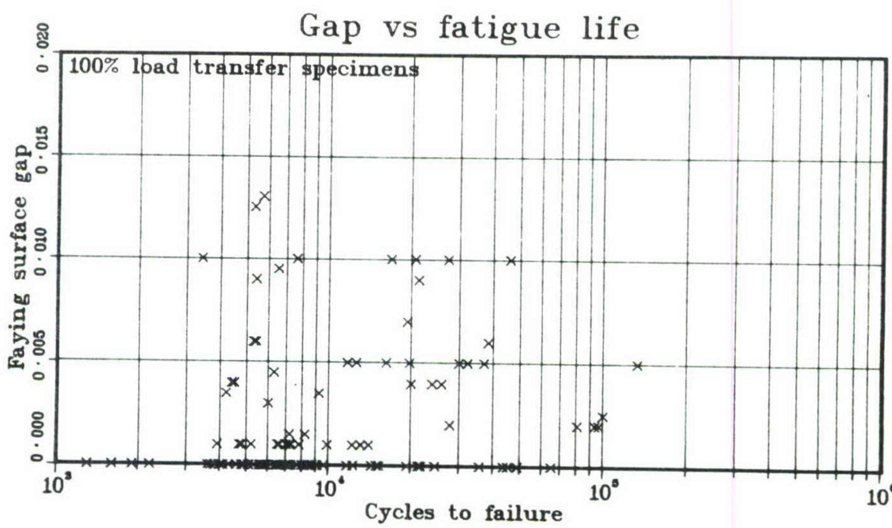

Figure 177. Gap vs. Fatigue Life for 100% Load Transfer Specimens

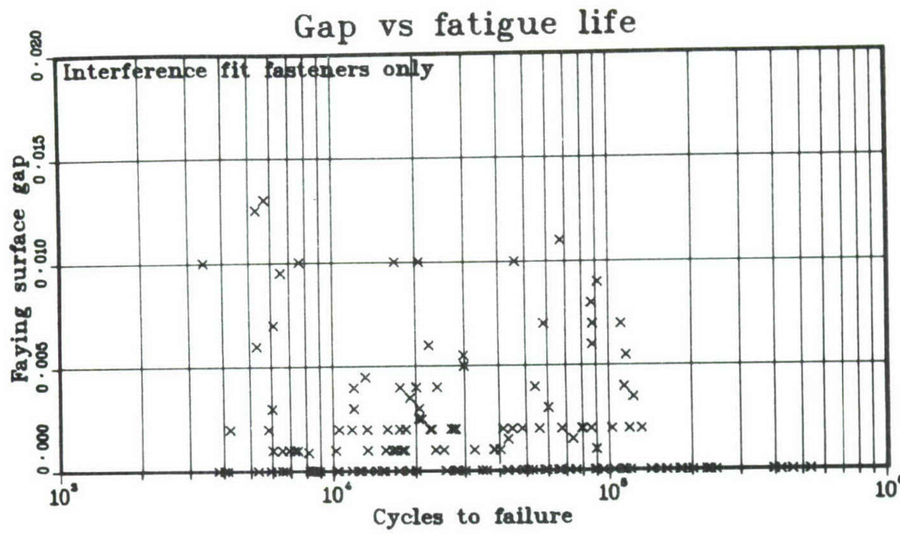

Figure 178. Gap vs. Fatigue Life for Interference Fit Fasteners Only

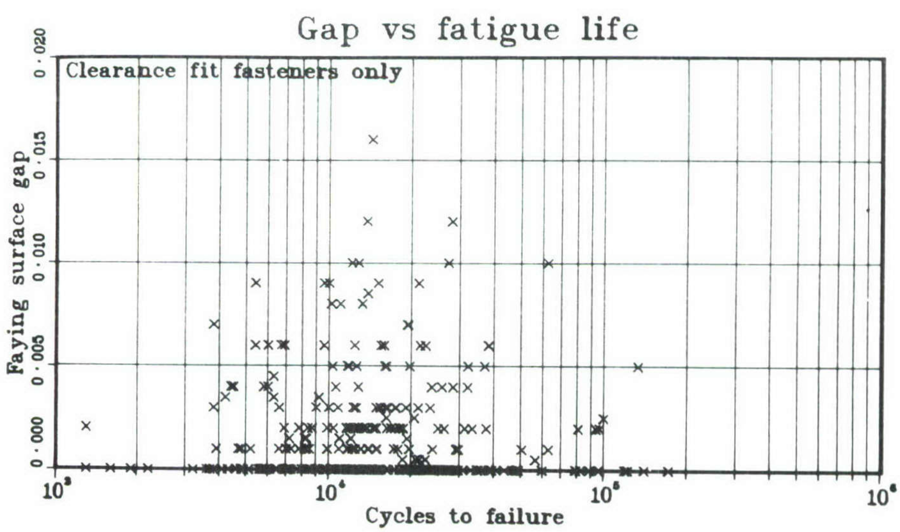

Figure 179. Gap vs. Fatigue Life for Clearance Fit Fasteners Only

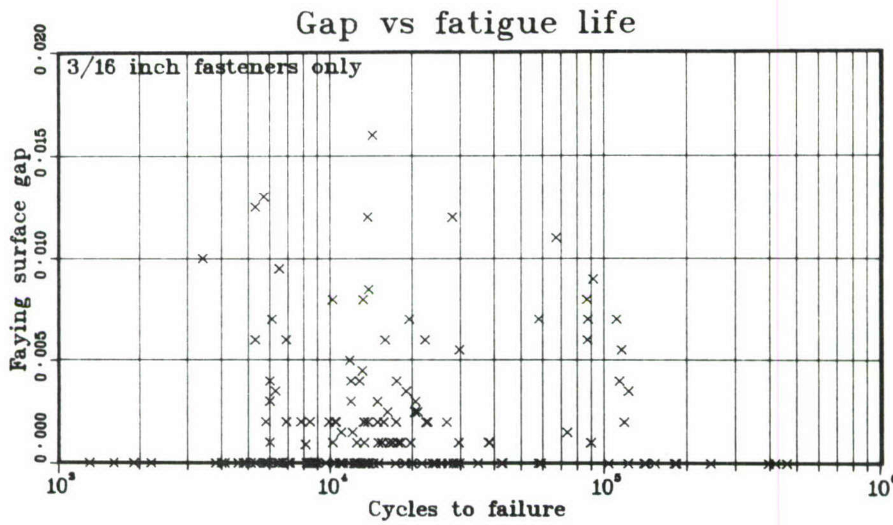

Figure 180. Gap vs. Fatigue Life for 3/16-Inch Fasteners Only

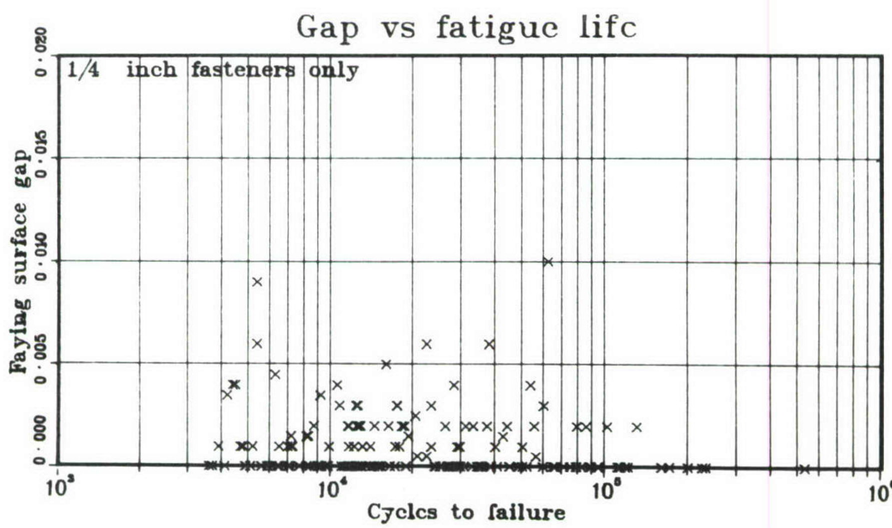

Figure 181. Gap vs. Fatigue Life for 1/4-Inch Fasteners Only

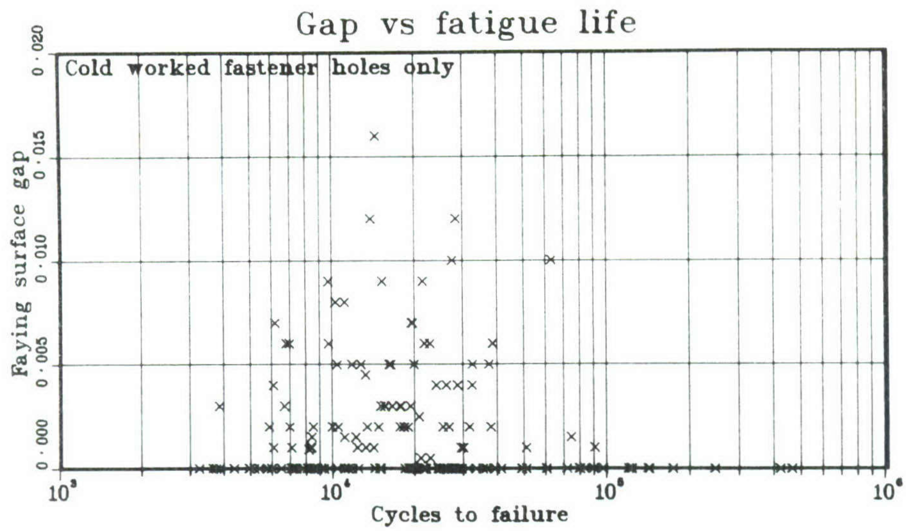

Figure 182. Gap vs. Fatigue Life for 5/16-Inch Fasteners Only

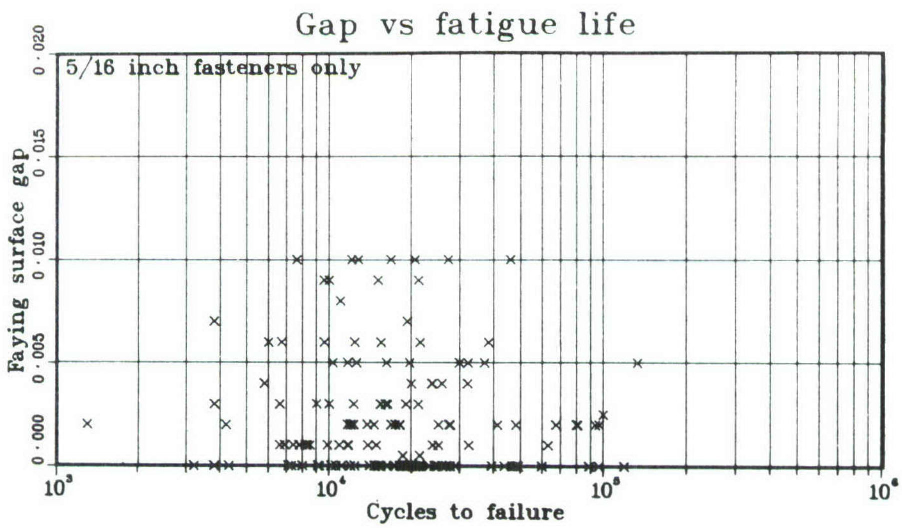

Figure 183. Gap vs. Fatigue Life for Cold-Worked Fastener Holes Only

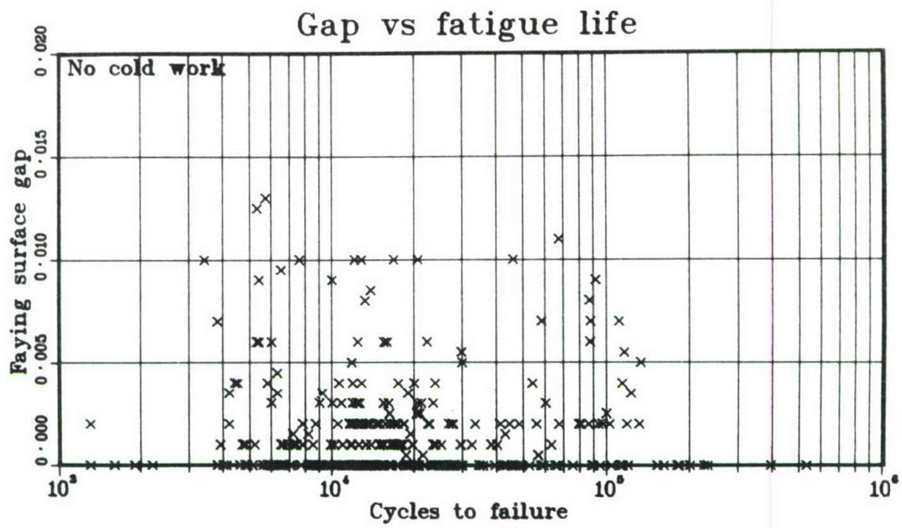

Figure 184. Gap vs. Fatigue Life for No Cold-Work

x. Variables Not in the Models

There are a number of possible variables which have not been included in the models. Some of them, such as fastener material, fastener material strength level, shim material, countersink roughness, fastener shank type, and fastener driving method, were either not used or only one type was used, and it was used consistently so that no regression analysis was possible.

Other variables, such as test temperature, collar material strength level, sheet material finish system, and head type were tested in models and were found not to be significant.

SECTION V

CONCLUSIONS

The object of this experimental program was to determine the influence of hole processing and joint variables on the fatigue life of mechanically fastened shear joints. This objective has been accomplished, and a series of predictive models, explaining from 47 to 86% of the variation in joint fatigue life, has been developed.

There were several variables associated with the type of collar and the collar material strength which could be removed from the model and replaced with a single term, fastener preload, without reducing the accuracy of the model. Similarly, the type of coating and fretting protection variables could be replaced with a single term for the sum of their thicknesses, simplifying the model.

Material availability limited the testing for effects of different fastener materials or fastener strengths, or different sheet materials. This of course greatly limits the ability to generalize from the results reported here. However, as future testing is accomplished on other materials and fasteners, and as the data from these tests are collected in computer files, it will be possible to extend the results of this series of tests to more general conditions.

Certainly, the greatest surprise in the models which were developed was the lack of sensitivity to the surface roughness of the hole. This was contrary to the intuitive expectations of the author and did not correspond to the commonly held belief in the aerospace industry that the surface roughness of the hole is significant in determining fatigue life. This deviation from the expected behavior of the fatigue specimens cannot be fully explained, but some speculation on the possible causes will be presented.

Fatigue crack initiation and growth is dependent on the state of stress present in the part. Certainly the influence of both fastener interference and hole cold-working demonstrate the effect of local

changes in the state of stress on time to failure. In drilling the rough holes used in this series of tests, the drill bits were forced into the specimens at the highest rate possible with the tools used. This aggressive and abusive handling of the specimens may have had effects beyond the desired hole roughening. While an undersized drill was used to drill the abusively drilled and intentionally roughened holes, the drill bit pushed rather than cut its way into the metal specimen. This drilling may have effectively cold-worked the holes. Of course, the amount of the cold-working could not be determined by the usual means of measuring the hole before and after the mandrel was passed through it.

There are at least two possible means of determining the stress state around the holes. The first technique would be to use an x-ray stress analysis device, such as the Fastress machine, and determine the stresses present at various points near the holes. Calibration of the equipment for the particular aluminum alloy used would be required in order to achieve reasonable accuracy. While the actual stress determinations can take place fairly rapidly, calibration can be very time consuming. Engineers familiar with the Fastress system estimate 600 hours effort to calibrate a new material in the machine.

A second possible technique would be to mount the specimen rigidly and produce a laser hologram of the specimen. This would allow the determination of the out-of-plane plastic deformation of the specimen in the region near the hole, and by comparing the extent of this deformation with the extent of deformation indicated in specimens having known amounts of cold-work, it should be possible to determine approximately the deformation of the specimen. From the deformations (plastic strains) present, it would be possible to obtain some idea as to the stress state present.

Both of these techniques would be challenging experimental exercises which might be fruitfully pursued by those individuals interested in experimental stress analysis techniques.

A prime consideration should be the minimization of the cost for an acceptable product quality level. This study indicates that fastener interference is a key parameter to achieving longer fatigue life of structural joints. Interference is determined by fastener diameter and hole diameter, and since fastener diameter is usually closely controlled by the fastener producer, hole diameter must be closely controlled during production. In reasonably good quality holes the diameter can be rapidly measured with simple gages, so that emphasis can be placed on controlling fastener interference at relatively low cost.

One item is apparent: good materials, good design, and good process specifications are important, but as it was expressed years ago, ". . . in the final analysis, then, it is 'the man with the wrench' who determines the strength of the joint (Reference 71);" it should now be said: "It is the man with the drill who determines the life of the joint."

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APPENDIX A

ANALYSIS OF THE EXPERIMENT DESIGN

After the experiment had been designed and target values established for the 120 specimen groups, the design was analyzed to determine whether significant imbalances existed in the design. In analyzing the design a 30-element code, which mathematically described the test conditions, was used. For each of the 120 specimen groups, the code elements were defined as:

X(1)	1.	protruding head fastener	-	60 cases
	-1.	countersink fastener	-	60 cases

Specimen Surface Treatment

	Bare	Alodined	Primed	Top-coated
X(2)	0	0	1.	-1.
X(3)	0	-2.	1.	1.
X(4)	-3.	1.	1.	1.
	30 cases	13 cases	60 cases	17 cases

Specimen Faying Surface Fretting Protection

	Lubricant	No Treatment	Sealant	Adhesive
X(5)	0	0	1.	-1.
X(6)	0	-2.	1.	1.
X(7)	-3.	1.	1.	1.
	12 cases	37 cases	60 cases	11 cases

Fastener Corrosion Protection at Installation

X(8)	1.	fastener installed wet	-	60 cases
	-1.	fastener installed dry	-	60 cases

Fastener Hole Preparation Technique

	Rough-ened	Abusively Drilled	Normal Drilled	Drilled and Reamed
X(9)	0	0	1.	-1.
X(10)	0	-2.	1.	1.
X(11)	-3.	1.	1.	1.
	30 cases	30 cases	30 cases	30 cases

X(12) hole diameter in inches; range of hole sizes:

.182 - .203 in. for 3/16 in. diameter fasteners - 40 cases

.242 - .265 in. for 1/4 in. diameter fasteners - 40 cases

.302 - .328 in. for 5/16 in. diameter fasteners - 40 cases

X(13) distance the countersink centerline is offset from the hole centerline in inches:

no offset - 45 cases

offset 1/8 hole diameter - 7 cases

offset 1/4 hole diameter - 8 cases

X(14) countersink depth in inches:

no countersink drilled - 75 cases

countersink drilled to 1/2 normal depth - 15 cases

countersink drilled to normal depth - 15 cases

countersink drilled to 1-1/2 normal depth - 15 cases

X(15) angle, in degrees, between the hole centerline and a line perpendicular to the specimen surface:

hole perpendicular to surface - 102 cases

hole is 2° from perpendicular - 9 cases

hole is 4° from perpendicular - 9 cases

X(16) angle, in degrees, between the countersink centerline and a line perpendicular to the specimen surface:

countersink perpendicular to surface - 27 cases

countersink is 2° from perpendicular - 9 cases

countersink is 4° from perpendicular - 9 cases

X(17) hole taper angle, in degrees:

0° - 108 cases

1° - 6 cases

2° - 6 cases

Collar Types

	None	Soft (Annealed)	Shear	Shear Coining	Tension	Tension Coining
X(18)	0	0	0	0	1.	-1.
X(19)	0	0	0	-2.	1.	1.
X(20)	0	0	-3.	1.	1.	1.
X(21)	0	-4.	1.	1.	1.	1.
X(22)	-5.	1.	1.	1.	1.	1.
Cases	12	12	36	12	36	12

Nominal Fastener Interference Level

	Clearance	Transition	Low Int.	High-Int.
X(23)	0	0	1.	-1.
X(24)	0	-2.	1.	1.
X(25)	-3.	1.	1.	1.
Cases	30	30	30	30

Nominal Hole Cold-Work Level

	None	Low	High
X(26)	0	1.	-1.
X(27)	-2.	1.	1.
Cases	80	20	20

Is the Hole Deburred?

X(28)	-1.	No	-	60 cases
	1.	Yes	-	60 cases

Is the Fatigue Test Stopped Prior to Failure and Fastener Removed and Reinstalled?

X(29)	-1.	No	-	114 cases
	1.	Yes	-	6 cases

Nominal Specimen Load Transfer Level

X(30)	.0	-	20 cases
	.05	-	50 cases
	.50	-	20 cases
	1.0	-	30 cases

The X values for each of the 120 test conditions were tabulated in a 30 by 120 matrix, A, and multiplied by A^T to obtain the 30 by 30 C matrix using the IMSL computer subroutine VMULFF.

The C matrix was inverted and put in the D matrix using the IMSL computer subroutine LINV2F.

The F matrix, which is a diagonal matrix, is formed by taking the square root of the inverse of the diagonal elements of the C matrix.

G = F D F to form the correlation matrix. Examining the G matrix shows several off diagonal nonzero elements. The G matrix can be rearranged to group these nonzero elements. The reordered G matrix is:

i \ j	1	14	4	5	6	7	12	29	...	30
1	1.	.64								
14		1.			All other values 0.					
4			1.	-.47	.40	0.	.39	0.		
5				1.	-.60	0.	-.23	0.		
6					1.	0.	0.	0.		
7						1.	-.47	0.		
12							1.	-.50		
29		Symmetric						1.		
⋮									1.	
30										1.

Values less than .3 are taken as zero.

Matrix elements having a value of greater than .3 represent possible imbalances in the experiment design. Examination of these elements reveals many cases where physical necessities forced the

values to the levels shown, however. The following correlation coefficients can be explained as:

the 1 - 14 correlation is explained by countersinks only being drilled for countersink head fasteners

the 4 - 5 correlation reflects the fact that the adhesive can be used only on bare specimens, since good adhesion occurs against clean metal only

the 4 - 6 correlation occurs because there are very vew "no treatment" faying surface conditions on bare specimens

the 5 - 12 correlation is because of the adhesive only being used in a few cases

the 4 - 12 correlation results from the imbalance in the number of faying surface treatment conditions and is not being significant

the 7 - 12 correlation is not believed to have any physical significance. It is probably a result of the relatively few lubricated specimens, and it represents a random imbalance in the experiment

the 12 - 29 correlation is caused by the few cases in which fastener removal does take place. This correlation is believed to be caused by random events in a small population

From this analysis it is obvious that the experiment is reasonably well balanced. The few instabilities present result from either small proportions of the population having the attribute or from the nature of the attribute forcing an imbalance into the design.

The conclusion drawn from this analysis is that this design is not likely to be improved by being reaccomplished. Therefore, the experiment should continue with this design.

APPENDIX B

SPECIMEN TEST CONDITIONS

On the computer listing below are the descriptions of the specimen test configurations and conditions by specimen sequence number.

SEQ NO.	DIAM. 16THS	HEAD STYLE	CORROSION PROTECTION	FAYING SURFACE	INSTALLATION	HOLE PREP.	HOLE DIAM	CSK OFST	CSK DEPTH	HOLE ANG.	CSK ANG	HOLE TAPER	COLLAR STYLE	INTERFERENCE	COLD WORK	MANDREL SIZE	DEBURR	REMOVALS	LOAD TRNS
1	3	COUNTERSNK	PRIMED	NONE	WET	DRILL-REAM	.191	0.000	.111	0.	2.	0.	SHEAR	CLEARANCE	N/A	0.000	NONE	NO	0%
2	3	COUNTERSNK	PRIMED	NONE	WET	DRILL-REAM	.191	0.000	.111	0.	2.	0.	SHEAR	CLEARANCE	N/A	0.000	NONE	NO	0%
3	3	COUNTERSNK	PRIMED	NONE	WET	DRILL-REAM	.191	0.000	.111	0.	2.	0.	SHEAR	CLEARANCE	N/A	0.000	NONE	NO	0%
4	3	COUNTERSNK	PRIMED	NONE	WET	DRILL-REAM	.191	0.000	.111	0.	2.	0.	SHEAR	CLEARANCE	N/A	0.000	NONE	NO	0%
5	3	COUNTERSNK	PRIMED	NONE	WET	ROUGHEN	.182	.023	.074	4.	4.	0.	SHEAR	HIGH	N/A	0.000	DEBURR	NO	0%
6	3	COUNTERSNK	PRIMED	NONE	WET	ROUGHEN	.182	.023	.074	4.	4.	0.	SHEAR	HIGH	N/A	0.000	DEBURR	NO	0%
7	3	COUNTERSNK	PRIMED	NONE	WET	ROUGHEN	.182	.023	.074	4.	4.	0.	SHEAR	HIGH	N/A	0.000	DEBURR	NO	0%
8	3	COUNTERSNK	PRIMED	NONE	WET	ROUGHEN	.182	.023	.074	4.	4.	0.	SHEAR	HIGH	N/A	0.000	DEBURR	NO	0%
9	3	COUNTERSNK	ALODINE	NONE	WET	DRILL-REAM	.191	.047	.037	2.	4.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	0%
10	3	COUNTERSNK	ALODINE	NONE	WET	DRILL-REAM	.191	.047	.037	2.	4.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	0%
11	3	COUNTERSNK	ALODINE	NONE	WET	DRILL-REAM	.191	.047	.037	2.	4.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	0%
12	3	COUNTERSNK	ALODINE	NONE	WET	DRILL-REAM	.191	.047	.037	2.	4.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	0%
13	3	PROTRUDING	TOP COAT	NONE	WET	DRILL-REAM	.199	0.000	0.000	0.	0.	0.	TENSION	HIGH	HIGH	.189	DEBURR	NO	0%
14	3	PROTRUDING	TOP COAT	NONE	WET	DRILL-REAM	.199	0.000	0.000	0.	0.	0.	TENSION	HIGH	HIGH	.189	DEBURR	NO	0%
15	3	PROTRUDING	TOP COAT	NONE	WET	DRILL-REAM	.199	0.000	0.000	0.	0.	0.	TENSION	HIGH	HIGH	.189	DEBURR	NO	0%
16	3	PROTRUDING	TOP COAT	NONE	WET	DRILL-REAM	.199	0.000	0.000	0.	0.	0.	TENSION	HIGH	HIGH	.189	DEBURR	NO	0%
17	3	PROTRUDING	PRIMED	NONE	DRY	ABUS DRILL	.189	0.000	0.000	0.	0.	1.	TENS-COIN	TRANSITION	N/A	0.000	NONE	NO	0%
18	3	PROTRUDING	PRIMED	NONE	DRY	ABUS DRILL	.189	0.000	0.000	0.	0.	1.	TENS-COIN	TRANSITION	N/A	0.000	NONE	NO	0%
19	3	PROTRUDING	PRIMED	NONE	DRY	ABUS DRILL	.189	0.000	0.000	0.	0.	1.	TENS-COIN	TRANSITION	N/A	0.000	NONE	NO	0%
20	3	PROTRUDING	PRIMED	NONE	DRY	ABUS DRILL	.189	0.000	0.000	0.	0.	1.	TENS-COIN	TRANSITION	N/A	0.000	NONE	NO	0%
21	3	PROTRUDING	BARE	NONE	WET	ABUS DRILL	.191	0.000	0.000	0.	0.	0.	SOFT	CLEARANCE	N/A	0.000	NONE	NO	0%
22	3	PROTRUDING	BARE	NONE	WET	ABUS DRILL	.191	0.000	0.000	0.	0.	0.	SOFT	CLEARANCE	N/A	0.000	NONE	NO	0%
23	3	PROTRUDING	BARE	NONE	WET	ABUS DRILL	.191	0.000	0.000	0.	0.	0.	SOFT	CLEARANCE	N/A	0.000	NONE	NO	0%
24	3	PROTRUDING	BARE	NONE	WET	ABUS DRILL	.191	0.000	0.000	0.	0.	0.	SOFT	CLEARANCE	N/A	0.000	NONE	NO	0%
25	3	PROTRUDING	PRIMED	NONE	DRY	DRILL	.182	0.000	0.000	0.	0.	2.	NONE	HIGH	N/A	0.000	NONE	NO	0%
26	3	PROTRUDING	PRIMED	NONE	DRY	DRILL	.182	0.000	0.000	0.	0.	2.	NONE	HIGH	N/A	0.000	NONE	NO	0%
27	3	PROTRUDING	PRIMED	NONE	DRY	DRILL	.182	0.000	0.000	0.	0.	2.	NONE	HIGH	N/A	0.000	NONE	NO	0%
28	3	PROTRUDING	PRIMED	NONE	DRY	DRILL	.182	0.000	0.000	0.	0.	2.	NONE	HIGH	N/A	0.000	NONE	NO	0%
29	4	COUNTERSNK	PRIMED	NONE	DRY	DRILL-REAM	.251	0.000	.165	2.	0.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	0%
30	4	COUNTERSNK	PRIMED	NONE	DRY	DRILL-REAM	.251	0.000	.165	2.	0.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	0%
31	4	COUNTERSNK	PRIMED	NONE	DRY	DRILL-REAM	.251	0.000	.165	2.	0.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	0%
32	4	COUNTERSNK	PRIMED	NONE	DRY	DRILL-REAM	.251	0.000	.165	2.	0.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	0%
33	4	COUNTERSNK	PRIMED	NONE	WET	DRILL	.265	0.000	0.000	4.	0.	0.	TENSION	CLEARANCE	LOW	.254	DEBURR	NO	0%
34	4	COUNTERSNK	PRIMED	NONE	WET	DRILL	.265	0.000	0.000	4.	0.	0.	TENSION	CLEARANCE	LOW	.254	DEBURR	NO	0%
35	4	COUNTERSNK	PRIMED	NONE	WET	DRILL	.265	0.000	0.000	4.	0.	0.	TENSION	CLEARANCE	LOW	.254	DEBURR	NO	0%
36	4	COUNTERSNK	PRIMED	NONE	WET	DRILL	.265	0.000	0.000	4.	0.	0.	TENSION	CLEARANCE	LOW	.254	DEBURR	NO	0%
37	4	COUNTERSNK	PRIMED	NONE	DRY	ROUGHEN	.261	0.000	.110	0.	0.	0.	SHEAR	LOW	HIGH	.255	DEBURR	NO	0%
38	4	COUNTERSNK	PRIMED	NONE	DRY	ROUGHEN	.261	0.000	.110	0.	0.	0.	SHEAR	LOW	HIGH	.255	DEBURR	NO	0%
39	4	COUNTERSNK	PRIMED	NONE	DRY	ROUGHEN	.261	0.000	.110	0.	0.	0.	SHEAR	LOW	HIGH	.255	DEBURR	NO	0%
40	4	COUNTERSNK	PRIMED	NONE	DRY	ROUGHEN	.261	0.000	.110	0.	0.	0.	SHEAR	LOW	HIGH	.255	DEBURR	NO	0%

SEQ NO.	DIAM. 16THS	HEAD STYLE	CORROSION PROTECTION	FAYING SURFACE	INSTAL-LATION	HOLE PREP.	HOLE DIAM	CSK DEST	CSK DEPTH	HOLE ANG.	CSK ANG	HOLE TAPER	COLLAR STYLE	INTER-FERENCE	COLD WORK	MANDREL SIZE	DE-BURR	REMO-VALS	LOAD TRNS
41	4	PROTRUDING	PRIMED	NONE	WET	ROUGHEN	.242	0.000	0.000	0.	0.	0.	SHEARCOIN	HIGH	N/A	0.000	NONE	NO	0%
42	4	PROTRUDING	PRIMED	NONE	WET	ROUGHEN	.242	0.000	0.000	0.	0.	0.	SHEARCOIN	HIGH	N/A	0.000	NONE	NO	0%
43	4	PROTRUDING	PRIMED	NONE	WET	ROUGHEN	.242	0.000	0.000	0.	0.	0.	SHEARCOIN	HIGH	N/A	0.000	NONE	NO	0%
44	4	PROTRUDING	PRIMED	NONE	WET	ROUGHEN	.242	0.000	0.000	0.	0.	0.	SHEARCOIN	HIGH	N/A	0.000	NONE	NO	0%
45	4	PROTRUDING	BARE	NONE	DRY	ABUS DRILL	.242	0.000	0.000	0.	0.	0.	SHEAR	HIGH	N/A	0.000	DEBURR	REMOVAL	0%
46	4	PROTRUDING	BARE	NONE	DRY	ABUS DRILL	.242	0.000	0.000	0.	0.	0.	SHEAR	HIGH	N/A	0.000	DEBURR	REMOVAL	0%
47	4	PROTRUDING	BARE	NONE	DRY	ABUS DRILL	.242	0.000	0.000	0.	0.	0.	SHEAR	HIGH	N/A	0.000	DEBURR	REMOVAL	0%
48	4	PROTRUDING	BARE	NONE	DRY	ABUS DRILL	.242	0.000	0.000	0.	0.	0.	SHEAR	HIGH	N/A	0.000	DEBURR	REMOVAL	0%
49	4	PROTRUDING	BARE	NONE	WET	DRILL-REAM	.261	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	HIGH	.254	NONE	NO	0%
50	4	PROTRUDING	BARE	NONE	WET	DRILL-REAM	.261	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	HIGH	.254	NONE	NO	0%
51	4	PROTRUDING	BARE	NONE	WET	DRILL-REAM	.261	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	HIGH	.254	NONE	NO	0%
52	4	PROTRUDING	BARE	NONE	WET	DRILL-REAM	.261	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	HIGH	.254	NONE	NO	0%
53	4	PROTRUDING	PRIMED	NONE	DRY	DRILL-REAM	.265	0.000	0.000	0.	0.	0.	TENS-COIN	TRANSITION	LOW	.252	DEBURR	NO	0%
54	4	PROTRUDING	PRIMED	NONE	DRY	DRILL-REAM	.265	0.000	0.000	0.	0.	0.	TENS-COIN	TRANSITION	LOW	.252	DEBURR	NO	0%
55	4	PROTRUDING	PRIMED	NONE	DRY	DRILL-REAM	.265	0.000	0.000	0.	0.	0.	TENS-COIN	TRANSITION	LOW	.252	DEBURR	NO	0%
56	4	PROTRUDING	PRIMED	NONE	DRY	DRILL-REAM	.265	0.000	0.000	0.	0.	0.	TENS-COIN	TRANSITION	LOW	.252	DEBURR	NO	0%
57	5	PROTRUDING	TOP COAT	NONE	WET	ABUS DRILL	.311	0.000	0.000	0.	0.	0.	SHEAR	LOW	N/A	0.000	DEBURR	NO	0%
58	5	PROTRUDING	TOP COAT	NONE	WET	ABUS DRILL	.311	0.000	0.000	0.	0.	0.	SHEAR	LOW	N/A	0.000	DEBURR	NO	0%
59	5	PROTRUDING	TOP COAT	NONE	WET	ABUS DRILL	.311	0.000	0.000	0.	0.	0.	SHEAR	LOW	N/A	0.000	DEBURR	NO	0%
60	5	PROTRUDING	TOP COAT	NONE	WET	ABUS DRILL	.311	0.000	0.000	0.	0.	0.	SHEAR	LOW	N/A	0.000	DEBURR	NO	0%
61	5	PROTRUDING	BARE	NONE	DRY	DRILL	.311	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	DEBURR	NO	0%
62	5	PROTRUDING	BARE	NONE	DRY	DRILL	.311	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	DEBURR	NO	0%
63	5	PROTRUDING	BARE	NONE	DRY	DRILL	.311	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	DEBURR	NO	0%
64	5	PROTRUDING	BARE	NONE	DRY	DRILL	.311	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	DEBURR	NO	0%
65	5	PROTRUDING	PRIMED	NONE	WET	ROUGHEN	.311	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	DEBURR	NO	0%
66	5	PROTRUDING	PRIMED	NONE	WET	ROUGHEN	.311	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	DEBURR	NO	0%
67	5	PROTRUDING	PRIMED	NONE	WET	ROUGHEN	.311	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	DEBURR	NO	0%
68	5	PROTRUDING	PRIMED	NONE	WET	ROUGHEN	.311	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	DEBURR	NO	0%
69	5	COUNTERSNK	TOP COAT	NONE	WET	DRILL	.323	0.000	0.000	2.	0.	0.	SHEARCOIN	LOW	HIGH	.314	DEBURR	NO	0%
70	5	COUNTERSNK	TOP COAT	NONE	WET	DRILL	.323	0.000	0.000	2.	0.	0.	SHEARCOIN	LOW	HIGH	.314	DEBURR	NO	0%
71	5	COUNTERSNK	TOP COAT	NONE	WET	DRILL	.323	0.000	0.000	2.	0.	0.	SHEARCOIN	LOW	HIGH	.314	DEBURR	NO	0%
72	5	COUNTERSNK	TOP COAT	NONE	WET	DRILL	.323	0.000	0.000	2.	0.	0.	SHEARCOIN	LOW	HIGH	.314	DEBURR	NO	0%
73	5	COUNTERSNK	BARE	NONE	WET	DRILL-REAM	.323	0.000	.069	0.	0.	0.	SHEAR	LOW	LOW	.315	NONE	NO	0%
74	5	COUNTERSNK	BARE	NONE	WET	DRILL-REAM	.323	0.000	.069	0.	0.	0.	SHEAR	LOW	LOW	.315	NONE	NO	0%
75	5	COUNTERSNK	BARE	NONE	WET	DRILL-REAM	.323	0.000	.069	0.	0.	0.	SHEAR	LOW	LOW	.315	NONE	NO	0%
76	5	COUNTERSNK	BARE	NONE	WET	DRILL-REAM	.323	0.000	.069	0.	0.	0.	SHEAR	LOW	LOW	.315	NONE	NO	0%
77	5	COUNTERSNK	ALODINE	NONE	DRY	ABUS DRILL	.323	.038	.069	0.	0.	0.	SOFT	LOW	LOW	.315	NONE	NO	0%
78	5	COUNTERSNK	ALODINE	NONE	DRY	ABUS DRILL	.323	.038	.069	0.	0.	0.	SOFT	LOW	LOW	.315	NONE	NO	0%
79	5	COUNTERSNK	ALODINE	NONE	DRY	ABUS DRILL	.323	.038	.069	0.	0.	0.	SOFT	LOW	LOW	.315	NONE	NO	0%
80	5	COUNTERSNK	ALODINE	NONE	DRY	ABUS DRILL	.323	.038	.069	0.	0.	0.	SOFT	LOW	LOW	.315	NONE	NO	0%

SEQ NO.	DIAM. 16THS	HEAD STYLE	CORROSION PROTECTION	FAYING SURFACE	INSTAL-LATION	HOLE PREP.	HOLE DIAM	CSK OFST	CSK DEPTH	HOLE ANG.	CSK ANG	HOLE TAPER	COLLAR STYLE	INTER-FERENCE	COLD WORK	MANDREL SIZE	DE-BURR	REMO-VALS	LOAD TRNS
81	3	COUNTERSNK	BARE	ADHESIVE	WET	DRILL	.191	.047	.074	0.	2.	1.	SOFT	CLEARANCE	N/A	0.000	DEBURR	NO	5%
82	3	COUNTERSNK	BARE	ADHESIVE	WET	DRILL	.191	.047	.074	0.	2.	1.	SOFT	CLEARANCE	N/A	0.000	DEBURR	NO	5%
83	3	COUNTERSNK	BARE	ADHESIVE	WET	DRILL	.191	.047	.074	0.	2.	1.	SOFT	CLEARANCE	N/A	0.000	DEBURR	NO	5%
84	3	COUNTERSNK	BARE	ADHESIVE	WET	DRILL	.191	.047	.074	0.	2.	1.	SOFT	CLEARANCE	N/A	0.000	DEBURR	NO	5%
85	3	COUNTERSNK	PRIMED	SEALANT	WET	ABUS DRILL	.182	0.000	0.000	0.	0.	0.	TENS-COIN	HIGH	N/A	0.000	DEBURR	NO	5%
86	3	COUNTERSNK	PRIMED	SEALANT	WET	ABUS DRILL	.182	0.000	0.000	0.	0.	0.	TENS-COIN	HIGH	N/A	0.000	DEBURR	NO	5%
87	3	COUNTERSNK	PRIMED	SEALANT	WET	ABUS DRILL	.182	0.000	0.000	0.	0.	0.	TENS-COIN	HIGH	N/A	0.000	DEBURR	NO	5%
88	3	COUNTERSNK	PRIMED	SEALANT	WET	ABUS DRILL	.182	0.000	0.000	0.	0.	0.	TENS-COIN	HIGH	N/A	0.000	DEBURR	NO	5%
89	3	COUNTERSNK	PRIMED	NONE	WET	ABUS DRILL	.185	.047	.074	0.	0.	0.	NONE	LOW	N/A	0.000	NONE	NO	5%
90	3	COUNTERSNK	PRIMED	NONE	WET	ABUS DRILL	.185	.047	.074	0.	0.	0.	NONE	LOW	N/A	0.000	NONE	NO	5%
91	3	COUNTERSNK	PRIMED	NONE	WET	ABUS DRILL	.185	.047	.074	0.	0.	0.	NONE	LOW	N/A	0.000	NONE	NO	5%
92	3	COUNTERSNK	PRIMED	NONE	WET	ABUS DRILL	.185	.047	.074	0.	0.	0.	NONE	LOW	N/A	0.000	NONE	NO	5%
93	3	COUNTERSNK	TOP COAT	NONE	WET	ABUS DRILL	.182	0.000	0.000	0.	0.	2.	NONE	HIGH	N/A	0.000	NONE	NO	5%
94	3	COUNTERSNK	TOP COAT	NONE	WET	ABUS DRILL	.182	0.000	0.000	0.	0.	2.	NONE	HIGH	N/A	0.000	NONE	NO	5%
95	3	COUNTERSNK	TOP COAT	NONE	WET	ABUS DRILL	.182	0.000	0.000	0.	0.	2.	NONE	HIGH	N/A	0.000	NONE	NO	5%
96	3	COUNTERSNK	TOP COAT	NONE	WET	ABUS DRILL	.182	0.000	0.000	0.	0.	2.	NONE	HIGH	N/A	0.000	NONE	NO	5%
97	3	COUNTERSNK	PRIMED	SEALANT	WET	ROUGHEN	.191	0.000	.111	0.	4.	0.	SHEARCOIN	CLEARANCE	N/A	0.000	NONE	NO	5%
98	3	COUNTERSNK	PRIMED	SEALANT	WET	ROUGHEN	.191	0.000	.111	0.	4.	0.	SHEARCOIN	CLEARANCE	N/A	0.000	NONE	NO	5%
99	3	COUNTERSNK	PRIMED	SEALANT	WET	ROUGHEN	.191	0.000	.111	0.	4.	0.	SHEARCOIN	CLEARANCE	N/A	0.000	NONE	NO	5%
100	3	COUNTERSNK	PRIMED	SEALANT	WET	ROUGHEN	.191	0.000	.111	0.	4.	0.	SHEARCOIN	CLEARANCE	N/A	0.000	NONE	NO	5%
101	3	COUNTERSNK	TOP COAT	SEALANT	WET	ABUS DRILL	.191	0.000	.111	0.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	DEBURR	NO	5%
102	3	COUNTERSNK	TOP COAT	SEALANT	WET	ABUS DRILL	.191	0.000	.111	0.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	DEBURR	NO	5%
103	3	COUNTERSNK	TOP COAT	SEALANT	WET	ABUS DRILL	.191	0.000	.111	0.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	DEBURR	NO	5%
104	3	COUNTERSNK	TOP COAT	SEALANT	WET	ABUS DRILL	.191	0.000	.111	0.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	DEBURR	NO	5%
105	3	COUNTERSNK	BARE	NONE	WET	DRILL	.189	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	5%
106	3	COUNTERSNK	BARE	NONE	WET	DRILL	.189	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	5%
107	3	COUNTERSNK	BARE	NONE	WET	DRILL	.189	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	5%
108	3	COUNTERSNK	BARE	NONE	WET	DRILL	.189	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	5%
109	3	COUNTERSNK	BARE	SEALANT	WET	DRILL	.201	0.000	.111	0.	2.	0.	SHEAR	HIGH	LOW	.183	NONE	NO	5%
110	3	COUNTERSNK	BARE	SEALANT	WET	DRILL	.201	0.000	.111	0.	2.	0.	SHEAR	HIGH	LOW	.183	NONE	NO	5%
111	3	COUNTERSNK	BARE	SEALANT	WET	DRILL	.201	0.000	.111	0.	2.	0.	SHEAR	HIGH	LOW	.183	NONE	NO	5%
112	3	COUNTERSNK	BARE	SEALANT	WET	DRILL	.201	0.000	.111	0.	2.	0.	SHEAR	HIGH	LOW	.183	NONE	NO	5%
113	3	PROTRUDING	BARE	SEALANT	WET	DRILL	.182	0.000	0.000	0.	0.	0.	TENSION	HIGH	N/A	0.000	DEBURR	REMOVAL	5%
114	3	PROTRUDING	BARE	SEALANT	WET	DRILL	.182	0.000	0.000	0.	0.	0.	TENSION	HIGH	N/A	0.000	DEBURR	REMOVAL	5%
115	3	PROTRUDING	BARE	SEALANT	WET	DRILL	.182	0.000	0.000	0.	0.	0.	TENSION	HIGH	N/A	0.000	DEBURR	REMOVAL	5%
116	3	PROTRUDING	BARE	SEALANT	WET	DRILL	.182	0.000	0.000	0.	0.	0.	TENSION	HIGH	N/A	0.000	DEBURR	REMOVAL	5%
117	3	PROTRUDING	BARE	LUBRICANT	DRY	ROUGHEN	.182	0.000	0.000	0.	0.	0.	SHEARCOIN	HIGH	N/A	0.000	NONE	NO	5%
118	3	PROTRUDING	BARE	LUBRICANT	DRY	ROUGHEN	.182	0.000	0.000	0.	0.	0.	SHEARCOIN	HIGH	N/A	0.000	NONE	NO	5%
119	3	PROTRUDING	BARE	LUBRICANT	DRY	ROUGHEN	.182	0.000	0.000	0.	0.	0.	SHEARCOIN	HIGH	N/A	0.000	NONE	NO	5%
120	3	PROTRUDING	BARE	LUBRICANT	DRY	ROUGHEN	.182	0.000	0.000	0.	0.	0.	SHEARCOIN	HIGH	N/A	0.000	NONE	NO	5%

SEQ NO.	DIAM. 16THS	HEAD STYLE	CORROSION PROTECTION	FAYING SURFACE	INSTAL-LATION	HOLE PREP.	HOLE DIAM	CSK DEST	CSK DEPTH	HOLE ANG.	CSK ANG	HOLE TAPER	COLLAR STYLE	INTER-FERENCE	COLD WORK	MANDREL SIZE	DE-BURR	REMO-VALS	LOAD TRNS
121	3	PROTRUDING	PRIMED	NONE	DRY	DRILL	.189	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	5%
122	3	PROTRUDING	PRIMED	NONE	DRY	DRILL	.189	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	5%
123	3	PROTRUDING	PRIMED	NONE	DRY	DRILL	.189	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	5%
124	3	PROTRUDING	PRIMED	NONE	DRY	DRILL	.189	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	5%
125	3	PROTRUDING	ALODINE	NONE	WET	ABUS DRILL	.193	0.000	0.000	2.	0.	2.	TENSION	LOW	HIGH	.190	NONE	NO	5%
126	3	PROTRUDING	ALODINE	NONE	WET	ABUS DRILL	.193	0.000	0.000	2.	0.	2.	TENSION	LOW	HIGH	.190	NONE	NO	5%
127	3	PROTRUDING	ALODINE	NONE	WET	ABUS DRILL	.193	0.000	0.000	2.	0.	2.	TENSION	LOW	HIGH	.190	NONE	NO	5%
128	3	PROTRUDING	ALODINE	NONE	WET	ABUS DRILL	.193	0.000	0.000	2.	0.	2.	TENSION	LOW	HIGH	.190	NONE	NO	5%
129	3	PROTRUDING	PRIMED	NONE	WET	ROUGHEN	.189	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	NONE	NO	5%
130	3	PROTRUDING	PRIMED	NONE	WET	ROUGHEN	.189	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	NONE	NO	5%
131	3	PROTRUDING	PRIMED	NONE	WET	ROUGHEN	.189	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	NONE	NO	5%
132	3	PROTRUDING	PRIMED	NONE	WET	ROUGHEN	.189	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	NONE	NO	5%
133	3	PROTRUDING	PRIMED	NONE	DRY	DRILL-REAM	.193	0.000	0.000	0.	0.	0.	SHEAR	HIGH	HIGH	.183	DEBURR	NO	5%
134	3	PROTRUDING	PRIMED	NONE	DRY	DRILL-REAM	.193	0.000	0.000	0.	0.	0.	SHEAR	HIGH	HIGH	.183	DEBURR	NO	5%
135	3	PROTRUDING	PRIMED	NONE	DRY	DRILL-REAM	.193	0.000	0.000	0.	0.	0.	SHEAR	HIGH	HIGH	.183	DEBURR	NO	5%
136	3	PROTRUDING	PRIMED	NONE	DRY	DRILL-REAM	.193	0.000	0.000	0.	0.	0.	SHEAR	HIGH	HIGH	.183	DEBURR	NO	5%
137	3	PROTRUDING	PRIMED	NONE	WET	DRILL	.185	0.000	0.000	0.	0.	0.	TENSION	LOW	N/A	0.000	DEBURR	NO	5%
138	3	PROTRUDING	PRIMED	NONE	WET	DRILL	.185	0.000	0.000	0.	0.	0.	TENSION	LOW	N/A	0.000	DEBURR	NO	5%
139	3	PROTRUDING	PRIMED	NONE	WET	DRILL	.185	0.000	0.000	0.	0.	0.	TENSION	LOW	N/A	0.000	DEBURR	NO	5%
140	3	PROTRUDING	PRIMED	NONE	WET	DRILL	.185	0.000	0.000	0.	0.	0.	TENSION	LOW	N/A	0.000	DEBURR	NO	5%
141	3	PROTRUDING	PRIMED	NONE	WET	ABUS DRILL	.203	0.000	0.000	0.	0.	1.	SHEAR	CLEARANCE	HIGH	.193	DEBURR	NO	5%
142	3	PROTRUDING	PRIMED	NONE	WET	ABUS DRILL	.203	0.000	0.000	0.	0.	1.	SHEAR	CLEARANCE	HIGH	.193	DEBURR	NO	5%
143	3	PROTRUDING	PRIMED	NONE	WET	ABUS DRILL	.203	0.000	0.000	0.	0.	1.	SHEAR	CLEARANCE	HIGH	.193	DEBURR	NO	5%
144	3	PROTRUDING	PRIMED	NONE	WET	ABUS DRILL	.203	0.000	0.000	0.	0.	1.	SHEAR	CLEARANCE	HIGH	.193	DEBURR	NO	5%
145	4	PROTRUDING	TOP COAT	SEALANT	WET	ABUS DRILL	.245	0.000	0.000	0.	0.	0.	TENSION	LOW	N/A	0.000	NONE	NO	5%
146	4	PROTRUDING	TOP COAT	SEALANT	WET	ABUS DRILL	.245	0.000	0.000	0.	0.	0.	TENSION	LOW	N/A	0.000	NONE	NO	5%
147	4	PROTRUDING	TOP COAT	SEALANT	WET	ABUS DRILL	.245	0.000	0.000	0.	0.	0.	TENSION	LOW	N/A	0.000	NONE	NO	5%
148	4	PROTRUDING	TOP COAT	SEALANT	WET	ABUS DRILL	.245	0.000	0.000	0.	0.	0.	TENSION	LOW	N/A	0.000	NONE	NO	5%
149	4	PROTRUDING	PRIMED	SEALANT	DRY	ABUS DRILL	.261	0.000	0.000	0.	0.	0.	TENS-COIN	LOW	HIGH	.252	NONE	NO	5%
150	4	PROTRUDING	PRIMED	SEALANT	DRY	ABUS DRILL	.261	0.000	0.000	0.	0.	0.	TENS-COIN	LOW	HIGH	.252	NONE	NO	5%
151	4	PROTRUDING	PRIMED	SEALANT	DRY	ABUS DRILL	.261	0.000	0.000	0.	0.	0.	TENS-COIN	LOW	HIGH	.252	NONE	NO	5%
152	4	PROTRUDING	PRIMED	SEALANT	DRY	ABUS DRILL	.261	0.000	0.000	0.	0.	0.	TENS-COIN	LOW	HIGH	.252	NONE	NO	5%
153	4	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.257	0.000	0.000	0.	0.	0.	TENSION	HIGH	HIGH	.251	DEBURR	NO	5%
154	4	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.257	0.000	0.000	0.	0.	0.	TENSION	HIGH	HIGH	.251	DEBURR	NO	5%
155	4	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.257	0.000	0.000	0.	0.	0.	TENSION	HIGH	HIGH	.251	DEBURR	NO	5%
156	4	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.257	0.000	0.000	0.	0.	0.	TENSION	HIGH	HIGH	.251	DEBURR	NO	5%
157	4	PROTRUDING	ALODINE	SEALANT	WET	ABUS DRILL	.251	0.000	0.000	2.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	NONE	NO	5%
158	4	PROTRUDING	ALODINE	SEALANT	WET	ABUS DRILL	.251	0.000	0.000	2.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	NONE	NO	5%
159	4	PROTRUDING	ALODINE	SEALANT	WET	ABUS DRILL	.251	0.000	0.000	2.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	NONE	NO	5%
160	4	PROTRUDING	ALODINE	SEALANT	WET	ABUS DRILL	.251	0.000	0.000	2.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	NONE	NO	5%

SEQ NO.	DIAM. 16THS	HEAD STYLE	CORROSION PROTECTION	FAYING SURFACE	INSTAL-LATION	HOLE PREP.	HOLE DIAM	CSK DEST	CSK DEPTH	HOLE ANG.	CSK ANG	HOLE TAPER	COLLAR STYLE	INTER-FERENCE	COLD WORK	MANDREL SIZE	DE-BURR	REMO-VALS	LOAD TRNS
161	4	PROTRUDING	ALODINE	NONE	DRY	ABUS DRILL	.245	0.000	0.000	0.	0.	0.	SHEAR	LOW	N/A	0.000	DEBURR	NO	5%
162	4	PROTRUDING	ALODINE	NONE	DRY	ABUS DRILL	.245	0.000	0.000	0.	0.	0.	SHEAR	LOW	N/A	0.000	DEBURR	NO	5%
163	4	PROTRUDING	ALODINE	NONE	DRY	ABUS DRILL	.245	0.000	0.000	0.	0.	0.	SHEAR	LOW	N/A	0.000	DEBURR	NO	5%
164	4	PROTRUDING	ALODINE	NONE	DRY	ABUS DRILL	.245	0.000	0.000	0.	0.	0.	SHEAR	LOW	N/A	0.000	DEBURR	NO	5%
165	4	PROTRUDING	PRIMED	SEALANT	DRY	DRILL-REAM	.242	0.000	0.000	0.	0.	0.	NONE	HIGH	N/A	0.000	DEBURR	NO	5%
166	4	PROTRUDING	PRIMED	SEALANT	DRY	DRILL-REAM	.242	0.000	0.000	0.	0.	0.	NONE	HIGH	N/A	0.000	DEBURR	NO	5%
167	4	PROTRUDING	PRIMED	SEALANT	DRY	DRILL-REAM	.242	0.000	0.000	0.	0.	0.	NONE	HIGH	N/A	0.000	DEBURR	NO	5%
168	4	PROTRUDING	PRIMED	SEALANT	DRY	DRILL-REAM	.242	0.000	0.000	0.	0.	0.	NONE	HIGH	N/A	0.000	DEBURR	NO	5%
169	4	PROTRUDING	BARE	ADHESIVE	WET	ABUS DRILL	.249	0.000	0.000	4.	0.	2.	SHEAR	TRANSITION	N/A	0.000	DEBURR	REMOVAL	5%
170	4	PROTRUDING	BARE	ADHESIVE	WET	ABUS DRILL	.249	0.000	0.000	4.	0.	2.	SHEAR	TRANSITION	N/A	0.000	DEBURR	REMOVAL	5%
171	4	PROTRUDING	BARE	ADHESIVE	WET	ABUS DRILL	.249	0.000	0.000	4.	0.	2.	SHEAR	TRANSITION	N/A	0.000	DEBURR	REMOVAL	5%
172	4	PROTRUDING	BARE	ADHESIVE	WET	ABUS DRILL	.249	0.000	0.000	4.	0.	2.	SHEAR	TRANSITION	N/A	0.000	DEBURR	REMOVAL	5%
173	4	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.245	0.000	0.000	0.	0.	0.	SOFT	LOW	N/A	0.000	DEBURR	NO	5%
174	4	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.245	0.000	0.000	0.	0.	0.	SOFT	LOW	N/A	0.000	DEBURR	NO	5%
175	4	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.245	0.000	0.000	0.	0.	0.	SOFT	LOW	N/A	0.000	DEBURR	NO	5%
176	4	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.245	0.000	0.000	0.	0.	0.	SOFT	LOW	N/A	0.000	DEBURR	NO	5%
177	4	PROTRUDING	PRIMED	SEALANT	DRY	ROUGHEN	.261	0.000	0.000	0.	0.	0.	SOFT	LOW	LOW	.252	DEBURR	NO	5%
178	4	PROTRUDING	PRIMED	SEALANT	DRY	ROUGHEN	.261	0.000	0.000	0.	0.	0.	SOFT	LOW	LOW	.252	DEBURR	NO	5%
179	4	PROTRUDING	PRIMED	SEALANT	DRY	ROUGHEN	.261	0.000	0.000	0.	0.	0.	SOFT	LOW	LOW	.252	DEBURR	NO	5%
180	4	PROTRUDING	PRIMED	SEALANT	DRY	ROUGHEN	.261	0.000	0.000	0.	0.	0.	SOFT	LOW	LOW	.252	DEBURR	NO	5%
181	4	COUNTERSNK	PRIMED	NONE	DRY	ABUS DRILL	.246	0.000	.055	0.	4.	0.	SHEARCOIN	LOW	N/A	0.000	DEBURR	NO	5%
182	4	COUNTERSNK	PRIMED	NONE	DRY	ABUS DRILL	.245	0.000	.055	0.	4.	0.	SHEARCOIN	LOW	N/A	0.000	DEBURR	NO	5%
183	4	COUNTERSNK	PRIMED	NONE	DRY	ABUS DRILL	.245	0.000	.055	0.	4.	0.	SHEARCOIN	LOW	N/A	0.000	DEBURR	NO	5%
184	4	COUNTERSNK	PRIMED	NONE	DRY	ABUS DRILL	.245	0.000	.055	0.	4.	0.	SHEARCOIN	LOW	N/A	0.000	DEBURR	NO	5%
185	4	COUNTERSNK	PRIMED	SEALANT	WET	ABUS DRILL	.242	0.000	0.000	0.	0.	0.	TENSION	HIGH	N/A	0.000	NONE	NO	5%
186	4	COUNTERSNK	PRIMED	SEALANT	WET	ABUS DRILL	.242	0.000	0.000	0.	0.	0.	TENSION	HIGH	N/A	0.000	NONE	NO	5%
187	4	COUNTERSNK	PRIMED	SEALANT	WET	ABUS DRILL	.242	0.000	0.000	0.	0.	0.	TENSION	HIGH	N/A	0.000	NONE	NO	5%
188	4	COUNTERSNK	PRIMED	SEALANT	WET	ABUS DRILL	.242	0.000	0.000	0.	0.	0.	TENSION	HIGH	N/A	0.000	NONE	NO	5%
189	4	COUNTERSNK	PRIMED	SEALANT	DRY	ROUGHEN	.261	.031	.055	0.	2.	0.	SHEARCOIN	TRANSITION	LOW	.254	DEBURR	NO	5%
190	4	COUNTERSNK	PRIMED	SEALANT	DRY	ROUGHEN	.261	.031	.055	0.	2.	0.	SHEARCOIN	TRANSITION	LOW	.254	DEBURR	NO	5%
191	4	COUNTERSNK	PRIMED	SEALANT	DRY	ROUGHEN	.261	.031	.055	0.	2.	0.	SHEARCOIN	TRANSITION	LOW	.254	DEBURR	NO	5%
192	4	COUNTERSNK	PRIMED	SEALANT	DRY	ROUGHEN	.261	.031	.055	0.	2.	0.	SHEARCOIN	TRANSITION	LOW	.254	DEBURR	NO	5%
193	4	COUNTERSNK	BARE	ADHESIVE	DRY	DRILL-REAM	.251	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	DEBURR	REMOVAL	5%
194	4	COUNTERSNK	BARE	ADHESIVE	DRY	DRILL-REAM	.251	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	DEBURR	REMOVAL	5%
195	4	COUNTERSNK	BARE	ADHESIVE	DRY	DRILL-REAM	.251	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	DEBURR	REMOVAL	5%
196	4	COUNTERSNK	BARE	ADHESIVE	DRY	DRILL-REAM	.251	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	DEBURR	REMOVAL	5%
197	4	COUNTERSNK	PRIMED	SEALANT	DRY	ROUGHEN	.251	.031	.110	0.	4.	0.	TENS-COIN	CLEARANCE	N/A	0.000	DEBURR	NO	5%
198	4	COUNTERSNK	PRIMED	SEALANT	DRY	ROUGHEN	.251	.031	.110	0.	4.	0.	TENS-COIN	CLEARANCE	N/A	0.000	DEBURR	NO	5%
199	4	COUNTERSNK	PRIMED	SEALANT	DRY	ROUGHEN	.251	.031	.110	0.	4.	0.	TENS-COIN	CLEARANCE	N/A	0.000	DEBURR	NO	5%
200	4	COUNTERSNK	PRIMED	SEALANT	DRY	ROUGHEN	.251	.031	.110	0.	4.	0.	TENS-COIN	CLEARANCE	N/A	0.000	DEBURR	NO	5%

SEQ NO.	DIAM. 16THS	HEAD STYLE	CORROSION PROTECTION	FAYING SURFACE	INSTAL-LATION	HOLE PREP.	HOLE DIAM	CSK OFST	CSK DEPTH	HOLE ANG.	CSK ANG	HOLE TAPER	COLLAR STYLE	INTER-FERENCE	COLD WORK	MANDREL SIZE	DE-BURR	REMO-VALS	LOAD TRNS
201	4	COUNTERSNK	TOP COAT	NONE	DRY	ROUGHEN	.251	0.000	.055	0.	0.	0.	TENSION	LOW	HIGH	.252	NONE	NO	5%
202	4	COUNTERSNK	TOP COAT	NONE	DRY	ROUGHEN	.251	0.000	.055	0.	0.	0.	TENSION	LOW	HIGH	.252	NONE	NO	5%
203	4	COUNTERSNK	TOP COAT	NONE	DRY	ROUGHEN	.251	0.000	.055	0.	0.	0.	TENSION	LOW	HIGH	.252	NONE	NO	5%
204	4	COUNTERSNK	TOP COAT	NONE	DRY	ROUGHEN	.251	0.000	.055	0.	0.	0.	TENSION	LOW	HIGH	.252	NONE	NO	5%
205	4	COUNTERSNK	BARE	ADHESIVE	DRY	ROUGHEN	.261	0.000	.055	0.	0.	0.	SHEAR	CLEARANCE	LOW	.255	NONE	NO	5%
206	4	COUNTERSNK	BARE	ADHESIVE	DRY	ROUGHEN	.251	0.000	.055	0.	0.	0.	SHEAR	CLEARANCE	LOW	.255	NONE	NO	5%
207	4	COUNTERSNK	BARE	ADHESIVE	DRY	ROUGHEN	.261	0.000	.055	0.	0.	0.	SHEAR	CLEARANCE	LOW	.255	NONE	NO	5%
208	4	COUNTERSNK	BARE	ADHESIVE	DRY	ROUGHEN	.251	0.000	.055	0.	0.	0.	SHEAR	CLEARANCE	LOW	.255	NONE	NO	5%
209	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.242	0.000	.110	0.	0.	1.	SHEAR	HIGH	N/A	0.000	DEBURR	NO	5%
210	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.242	0.000	.110	0.	0.	1.	SHEAR	HIGH	N/A	0.000	DEBURR	NO	5%
211	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.242	0.000	.110	0.	0.	1.	SHEAR	HIGH	N/A	0.000	DEBURR	NO	5%
212	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.242	0.000	.110	0.	0.	1.	SHEAR	HIGH	N/A	0.000	DEBURR	NO	5%
213	5	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.313	0.000	0.000	0.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	NONE	NO	5%
214	5	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.313	0.000	0.000	0.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	NONE	NO	5%
215	5	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.313	0.000	0.000	0.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	NONE	NO	5%
216	5	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.313	0.000	0.000	0.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	NONE	NO	5%
217	5	PROTRUDING	PRIMED	NONE	DRY	ABUS DRILL	.311	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	5%
218	5	PROTRUDING	PRIMED	NONE	DRY	ABUS DRILL	.311	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	5%
219	5	PROTRUDING	PRIMED	NONE	DRY	ABUS DRILL	.311	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	5%
220	5	PROTRUDING	PRIMED	NONE	DRY	ABUS DRILL	.311	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	5%
221	5	PROTRUDING	PRIMED	SEALANT	WET	ABUS DRILL	.323	0.000	0.000	0.	0.	0.	NONE	LOW	HIGH	.315	NONE	NO	5%
222	5	PROTRUDING	PRIMED	SEALANT	WET	ABUS DRILL	.323	0.000	0.000	0.	0.	0.	NONE	LOW	HIGH	.315	NONE	NO	5%
223	5	PROTRUDING	PRIMED	SEALANT	WET	ABUS DRILL	.323	0.000	0.000	0.	0.	0.	NONE	LOW	HIGH	.315	NONE	NO	5%
224	5	PROTRUDING	PRIMED	SEALANT	WET	ABUS DRILL	.323	0.000	0.000	0.	0.	0.	NONE	LOW	HIGH	.315	NONE	NO	5%
225	5	PROTRUDING	BARE	ADHESIVE	DRY	DRILL-REAM	.311	0.000	0.000	4.	0.	0.	SOFT	LOW	N/A	0.000	NONE	NO	5%
226	5	PROTRUDING	BARE	ADHESIVE	DRY	DRILL-REAM	.311	0.000	0.000	4.	0.	0.	SOFT	LOW	N/A	0.000	NONE	NO	5%
227	5	PROTRUDING	BARE	ADHESIVE	DRY	DRILL-REAM	.311	0.000	0.000	4.	0.	0.	SOFT	LOW	N/A	0.000	NONE	NO	5%
228	5	PROTRUDING	BARE	ADHESIVE	DRY	DRILL-REAM	.311	0.000	0.000	4.	0.	0.	SOFT	LOW	N/A	0.000	NONE	NO	5%
229	5	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.311	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	DEBURR	NO	5%
230	5	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.311	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	DEBURR	NO	5%
231	5	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.311	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	DEBURR	NO	5%
232	5	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.311	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	DEBURR	NO	5%
233	5	PROTRUDING	TOP COAT	SEALANT	DRY	ABUS DRILL	.323	0.000	0.000	2.	0.	0.	SHEARCOIN	CLEARANCE	LOW	.318	NONE	NO	5%
234	5	PROTRUDING	TOP COAT	SEALANT	DRY	ABUS DRILL	.323	0.000	0.000	2.	0.	0.	SHEARCOIN	CLEARANCE	LOW	.318	NONE	NO	5%
235	5	PROTRUDING	TOP COAT	SEALANT	DRY	ABUS DRILL	.323	0.000	0.000	2.	0.	0.	SHEARCOIN	CLEARANCE	LOW	.318	NONE	NO	5%
236	5	PROTRUDING	TOP COAT	SEALANT	DRY	ABUS DRILL	.323	0.000	0.000	2.	0.	0.	SHEARCOIN	CLEARANCE	LOW	.318	NONE	NO	5%
237	5	PROTRUDING	TOP COAT	NONE	DRY	ROUGHEN	.313	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	5%
238	5	PROTRUDING	TOP COAT	NONE	DRY	ROUGHEN	.313	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	5%
239	5	PROTRUDING	TOP COAT	NONE	DRY	ROUGHEN	.313	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	5%
240	5	PROTRUDING	TOP COAT	NONE	DRY	ROUGHEN	.313	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	5%

SEQ NO.	DIAM. 16THS	HEAD STYLE	CORROSION PROTECTION	FAYING SURFACE	INSTAL-LATION	HOLE PREP.	HOLE DIAM	CSK OFST	CSK DEPTH	HOLE ANG.	CSK ANG	HOLE TAPER	COLLAR STYLE	INTER-FERENCE	COLD WORK	MANDREL SIZE	DE-BURR	REMO-VALS	LOAD TRNS
241	5	PROTRUDING	ALODINE	NONE	WET	ABUS DRILL	.323	0.000	0.000	0.	0.	1.	SHEAR	TRANSITION	LOW	.318	DEBURR	NO	5%
242	5	PROTRUDING	ALODINE	NONE	WET	ABUS DRILL	.323	0.000	0.000	0.	0.	1.	SHEAR	TRANSITION	LOW	.318	DEBURR	NO	5%
243	5	PROTRUDING	ALODINE	NONE	WET	ABUS DRILL	.323	0.000	0.000	0.	0.	1.	SHEAR	TRANSITION	LOW	.318	DEBURR	NO	5%
244	5	PROTRUDING	ALODINE	NONE	WET	ABUS DRILL	.323	0.000	0.000	0.	0.	1.	SHEAR	TRANSITION	LOW	.318	DEBURR	NO	5%
245	5	PROTRUDING	BARE	SEALANT	DRY	DRILL	.302	0.000	0.000	0.	0.	0.	NONE	HIGH	N/A	0.000	DEBURR	NO	5%
246	5	PROTRUDING	BARE	SEALANT	DRY	DRILL	.302	0.000	0.000	0.	0.	0.	NONE	HIGH	N/A	0.000	DEBURR	NO	5%
247	5	PROTRUDING	BARE	SEALANT	DRY	DRILL	.302	0.000	0.000	0.	0.	0.	NONE	HIGH	N/A	0.000	DEBURR	NO	5%
248	5	PROTRUDING	BARE	SEALANT	DRY	DRILL	.302	0.000	0.000	0.	0.	0.	NONE	HIGH	N/A	0.000	DEBURR	NO	5%
249	5	COUNTERSNK	PRIMED	SEALANT	WET	ABUS DRILL	.323	0.000	.205	0.	0.	0.	SOFT	TRANSITION	LOW	.318	DEBURR	NO	5%
250	5	COUNTERSNK	PRIMED	SEALANT	WET	ABUS DRILL	.323	0.000	.205	0.	0.	0.	SOFT	TRANSITION	LOW	.318	DEBURR	NO	5%
251	5	COUNTERSNK	PRIMED	SEALANT	WET	ABUS DRILL	.323	0.000	.205	0.	0.	0.	SOFT	TRANSITION	LOW	.318	DEBURR	NO	5%
252	5	COUNTERSNK	PRIMED	SEALANT	WET	ABUS DRILL	.323	0.000	.205	0.	0.	0.	SOFT	TRANSITION	LOW	.318	DEBURR	NO	5%
253	5	COUNTERSNK	PRIMED	SEALANT	DRY	ROUGHEN	.313	0.000	.205	4.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	NONE	NO	5%
254	5	COUNTERSNK	PRIMED	SEALANT	DRY	ROUGHEN	.313	0.000	.205	4.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	NONE	NO	5%
255	5	COUNTERSNK	PRIMED	SEALANT	DRY	ROUGHEN	.313	0.000	.205	4.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	NONE	NO	5%
256	5	COUNTERSNK	PRIMED	SEALANT	DRY	ROUGHEN	.313	0.000	.205	4.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	NONE	NO	5%
257	5	COUNTERSNK	PRIMED	NONE	DRY	DRILL-REAM	.311	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	NONE	NO	5%
258	5	COUNTERSNK	PRIMED	NONE	DRY	DRILL-REAM	.311	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	NONE	NO	5%
259	5	COUNTERSNK	PRIMED	NONE	DRY	DRILL-REAM	.311	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	NONE	NO	5%
260	5	COUNTERSNK	PRIMED	NONE	DRY	DRILL-REAM	.311	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	NONE	NO	5%
261	5	COUNTERSNK	ALODINE	NONE	DRY	DRILL-REAM	.323	0.000	.205	0.	0.	0.	TENSION	HIGH	LOW	.314	NONE	NO	5%
262	5	COUNTERSNK	ALODINE	NONE	DRY	DRILL-REAM	.323	0.000	.205	0.	0.	0.	TENSION	HIGH	LOW	.314	NONE	NO	5%
263	5	COUNTERSNK	ALODINE	NONE	DRY	DRILL-REAM	.323	0.000	.205	0.	0.	0.	TENSION	HIGH	LOW	.314	NONE	NO	5%
264	5	COUNTERSNK	ALODINE	NONE	DRY	DRILL-REAM	.323	0.000	.205	0.	0.	0.	TENSION	HIGH	LOW	.314	NONE	NO	5%
265	5	COUNTERSNK	TOP COAT	NONE	WET	ROUGHEN	.302	0.000	.069	0.	0.	0.	TENSION	HIGH	N/A	0.000	DEBURR	NO	5%
266	5	COUNTERSNK	TOP COAT	NONE	WET	ROUGHEN	.302	0.000	.069	0.	0.	0.	TENSION	HIGH	N/A	0.000	DEBURR	NO	5%
267	5	COUNTERSNK	TOP COAT	NONE	WET	ROUGHEN	.302	0.000	.069	0.	0.	0.	TENSION	HIGH	N/A	0.000	DEBURR	NO	5%
268	5	COUNTERSNK	TOP COAT	NONE	WET	ROUGHEN	.302	0.000	.069	0.	0.	0.	TENSION	HIGH	N/A	0.000	DEBURR	NO	5%
269	5	COUNTERSNK	BARE	ADHESIVE	DRY	DRILL	.311	0.000	.069	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	5%
270	5	COUNTERSNK	BARE	ADHESIVE	DRY	DRILL	.311	0.000	.069	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	5%
271	5	COUNTERSNK	BARE	ADHESIVE	DRY	DRILL	.311	0.000	.069	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	5%
272	5	COUNTERSNK	BARE	ADHESIVE	DRY	DRILL	.311	0.000	.069	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	5%
273	5	COUNTERSNK	BARE	SEALANT	DRY	DRILL	.311	0.000	.137	0.	0.	0.	TENS-COIN	TRANSITION	N/A	0.000	DEBURR	NO	5%
274	5	COUNTERSNK	BARE	SEALANT	DRY	DRILL	.311	0.000	.137	0.	0.	0.	TENS-COIN	TRANSITION	N/A	0.000	DEBURR	NO	5%
275	5	COUNTERSNK	BARE	SEALANT	DRY	DRILL	.311	0.000	.137	0.	0.	0.	TENS-COIN	TRANSITION	N/A	0.000	DEBURR	NO	5%
276	5	COUNTERSNK	BARE	SEALANT	DRY	DRILL	.311	0.000	.137	0.	0.	0.	TENS-COIN	TRANSITION	N/A	0.000	DEBURR	NO	5%
277	5	COUNTERSNK	BARE	SEALANT	WET	ABUS DRILL	.311	0.000	.137	0.	0.	0.	TENS-COIN	TRANSITION	N/A	0.000	DEBURR	NO	5%
278	5	COUNTERSNK	BARE	SEALANT	WET	ABUS DRILL	.311	0.000	.137	0.	0.	0.	TENS-COIN	TRANSITION	N/A	0.000	DEBURR	NO	5%
279	5	COUNTERSNK	BARE	SEALANT	WET	ABUS DRILL	.311	0.000	.137	0.	0.	0.	TENS-COIN	TRANSITION	N/A	0.000	DEBURR	NO	5%
280	5	COUNTERSNK	BARE	SEALANT	WET	ABUS DRILL	.311	0.000	.137	0.	0.	0.	TENS-COIN	TRANSITION	N/A	0.000	DEBURR	NO	5%

SEQ NO.	DIAM. 16THS	HEAD STYLE	CORROSION PROTECTION	FAYING SURFACE	INSTAL-LATION	HOLE PREP.	HOLE DIAM	CSK DEPT	CSK DEPTH	HOLE ANG.	CSK ANG	HOLE TAPER	COLLAR STYLE	INTER-FERENCE	COLD WORK	MANDREL SIZE	DE-BURR	REMO-VALS	LOAD TRNS
281	3	COUNTERSNK	BARE	LUBRICANT	DRY	ROUGHEN	.182	0.000	.037	2.	2.	0.	SHEAR	HIGH	N/A	0.000	DEBURR	REMOVAL	50%
282	3	COUNTERSNK	BARE	LUBRICANT	DRY	ROUGHEN	.182	0.000	.037	2.	2.	0.	SHEAR	HIGH	N/A	0.000	DEBURR	REMOVAL	50%
283	3	COUNTERSNK	BARE	LUBRICANT	DRY	ROUGHEN	.182	0.000	.037	2.	2.	0.	SHEAR	HIGH	N/A	0.000	DEBURR	REMOVAL	50%
284	3	COUNTERSNK	BARE	LUBRICANT	DRY	ROUGHEN	.182	0.000	.037	2.	2.	0.	SHEAR	HIGH	N/A	0.000	DEBURR	REMOVAL	50%
285	3	COUNTERSNK	PRIMED	SEALANT	WET	DRILL	.185	.047	.074	0.	0.	2.	TENS-COIN	LOW	N/A	0.000	DEBURR	NO	50%
286	3	COUNTERSNK	PRIMED	SEALANT	WET	DRILL	.185	.047	.074	0.	0.	2.	TENS-COIN	LOW	N/A	0.000	DEBURR	NO	50%
287	3	COUNTERSNK	PRIMED	SEALANT	WET	DRILL	.185	.047	.074	0.	0.	2.	TENS-COIN	LOW	N/A	0.000	DEBURR	NO	50%
288	3	COUNTERSNK	PRIMED	SEALANT	WET	DRILL	.185	.047	.074	0.	0.	2.	TENS-COIN	LOW	N/A	0.000	DEBURR	NO	50%
289	3	COUNTERSNK	BARE	ADHESIVE	WET	DRILL	.185	0.000	0.000	4.	0.	0.	SHEAR	LOW	N/A	0.000	NONE	NO	50%
290	3	COUNTERSNK	BARE	ADHESIVE	WET	DRILL	.185	0.000	0.000	4.	0.	0.	SHEAR	LOW	N/A	0.000	NONE	NO	50%
291	3	COUNTERSNK	BARE	ADHESIVE	WET	DRILL	.185	0.000	0.000	4.	0.	0.	SHEAR	LOW	N/A	0.000	NONE	NO	50%
292	3	COUNTERSNK	BARE	ADHESIVE	WET	DRILL	.185	0.000	0.000	4.	0.	0.	SHEAR	LOW	N/A	0.000	NONE	NO	50%
293	3	COUNTERSNK	PRIMED	SEALANT	WET	ROUGHEN	.203	0.000	.111	0.	0.	0.	TENSION	LOW	LOW	.190	NONE	NO	50%
294	3	COUNTERSNK	PRIMED	SEALANT	WET	ROUGHEN	.203	0.000	.111	0.	0.	0.	TENSION	LOW	LOW	.190	NONE	NO	50%
295	3	COUNTERSNK	PRIMED	SEALANT	WET	ROUGHEN	.203	0.000	.111	0.	0.	0.	TENSION	LOW	LOW	.190	NONE	NO	50%
296	3	COUNTERSNK	PRIMED	SEALANT	WET	ROUGHEN	.203	0.000	.111	0.	0.	0.	TENSION	LOW	LOW	.190	NONE	NO	50%
297	3	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.203	0.000	0.000	4.	0.	0.	TENSION	CLEARANCE	LOW	.192	NONE	NO	50%
298	3	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.203	0.000	0.000	4.	0.	0.	TENSION	CLEARANCE	LOW	.192	NONE	NO	50%
299	3	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.203	0.000	0.000	4.	0.	0.	TENSION	CLEARANCE	LOW	.192	NONE	NO	50%
300	3	PROTRUDING	PRIMED	SEALANT	WET	ROUGHEN	.203	0.000	0.000	4.	0.	0.	TENSION	CLEARANCE	LOW	.192	NONE	NO	50%
301	3	PROTRUDING	BARE	ADHESIVE	DRY	DRILL-REAM	.201	0.000	0.000	0.	0.	0.	SHEARCOIN	LOW	HIGH	.190	DEBURR	NO	50%
302	3	PROTRUDING	BARE	ADHESIVE	DRY	DRILL-REAM	.201	0.000	0.000	0.	0.	0.	SHEARCOIN	LOW	HIGH	.190	DEBURR	NO	50%
303	3	PROTRUDING	BARE	ADHESIVE	DRY	DRILL-REAM	.201	0.000	0.000	0.	0.	0.	SHEARCOIN	LOW	HIGH	.190	DEBURR	NO	50%
304	3	PROTRUDING	BARE	ADHESIVE	DRY	DRILL-REAM	.201	0.000	0.000	0.	0.	0.	SHEARCOIN	LOW	HIGH	.190	DEBURR	NO	50%
305	3	PROTRUDING	PRIMED	SEALANT	DRY	DRILL-REAM	.182	0.000	0.000	0.	0.	0.	SOFT	HIGH	N/A	0.000	NONE	NO	50%
306	3	PROTRUDING	PRIMED	SEALANT	DRY	DRILL-REAM	.182	0.000	0.000	0.	0.	0.	SOFT	HIGH	N/A	0.000	NONE	NO	50%
307	3	PROTRUDING	PRIMED	SEALANT	DRY	DRILL-REAM	.182	0.000	0.000	0.	0.	0.	SOFT	HIGH	N/A	0.000	NONE	NO	50%
308	3	PROTRUDING	PRIMED	SEALANT	DRY	DRILL-REAM	.182	0.000	0.000	0.	0.	0.	SOFT	HIGH	N/A	0.000	NONE	NO	50%
309	4	COUNTERSNK	PRIMED	NONE	DRY	DRILL	.249	0.000	.055	2.	0.	0.	TENSION	TRANSITION	N/A	0.000	DEBURR	NO	50%
310	4	COUNTERSNK	PRIMED	NONE	DRY	DRILL	.249	0.000	.055	2.	0.	0.	TENSION	TRANSITION	N/A	0.000	DEBURR	NO	50%
311	4	COUNTERSNK	PRIMED	NONE	DRY	DRILL	.249	0.000	.055	2.	0.	0.	TENSION	TRANSITION	N/A	0.000	DEBURR	NO	50%
312	4	COUNTERSNK	PRIMED	NONE	DRY	DRILL	.249	0.000	.055	2.	0.	0.	TENSION	TRANSITION	N/A	0.000	DEBURR	NO	50%
313	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.257	0.000	.165	4.	0.	0.	NONE	LOW	HIGH	.252	DEBURR	NO	50%
314	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.257	0.000	.165	4.	0.	0.	NONE	LOW	HIGH	.252	DEBURR	NO	50%
315	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.257	0.000	.165	4.	0.	0.	NONE	LOW	HIGH	.252	DEBURR	NO	50%
316	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.257	0.000	.165	4.	0.	0.	NONE	LOW	HIGH	.252	DEBURR	NO	50%
317	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL	.261	0.000	.110	0.	2.	1.	SHEAR	TRANSITION	HIGH	.254	NONE	NO	50%
318	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL	.261	0.000	.110	0.	2.	1.	SHEAR	TRANSITION	HIGH	.254	NONE	NO	50%
319	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL	.261	0.000	.110	0.	2.	1.	SHEAR	TRANSITION	HIGH	.254	NONE	NO	50%
320	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL	.261	0.000	.110	0.	2.	1.	SHEAR	TRANSITION	HIGH	.254	NONE	NO	50%

SEQ NO.	DIAM. 16THS	HEAD STYLE	CORROSION PROTECTION	FAYING SURFACE	INSTAL-LATION	HOLE PREP.	HOLE DIAM	CSK OFST	CSK DEPTH	HOLE ANG.	CSK ANG	HOLE TAPER	COLLAR STYLE	INTER-FERENCE	COLE WORK	MANDREL SIZE	DE-BURR	REMO-VALS	LOAD TRNS
321	4	PROTRUDING	PRIMED	SEALANT	WET	DRILL-REAM	.249	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	DEBURR	NO	50%
322	4	PROTRUDING	PRIMED	SEALANT	WET	DRILL-REAM	.249	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	DEBURR	NO	50%
323	4	PROTRUDING	PRIMED	SEALANT	WET	DRILL-REAM	.249	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	DEBURR	NO	50%
324	4	PROTRUDING	PRIMED	SEALANT	WET	DRILL-REAM	.249	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	DEBURR	NO	50%
325	4	PROTRUDING	PRIMED	NONE	WET	DRILL-REAM	.251	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	DEBURR	NO	50%
326	4	PROTRUDING	PRIMED	NONE	WET	DRILL-REAM	.251	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	DEBURR	NO	50%
327	4	PROTRUDING	PRIMED	NONE	WET	DRILL-REAM	.251	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	DEBURR	NO	50%
328	4	PROTRUDING	PRIMED	NONE	WET	DRILL-REAM	.251	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	DEBURR	NO	50%
329	4	PROTRUDING	PRIMED	NONE	DRY	DRILL-REAM	.249	0.000	0.000	0.	0.	0.	SOFT	TRANSITION	N/A	0.000	NONE	NO	50%
330	4	PROTRUDING	PRIMED	NONE	DRY	DRILL-REAM	.249	0.000	0.000	0.	0.	0.	SOFT	TRANSITION	N/A	0.000	NONE	NO	50%
331	4	PROTRUDING	PRIMED	NONE	DRY	DRILL-REAM	.249	0.000	0.000	0.	0.	0.	SOFT	TRANSITION	N/A	0.000	NONE	NO	50%
332	4	PROTRUDING	PRIMED	NONE	DRY	DRILL-REAM	.249	0.000	0.000	0.	0.	0.	SOFT	TRANSITION	N/A	0.000	NONE	NO	50%
333	5	PROTRUDING	TOP COAT	NONE	WET	DRILL	.323	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	HIGH	.318	DEBURR	NO	50%
334	5	PROTRUDING	TOP COAT	NONE	WET	DRILL	.323	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	HIGH	.318	DEBURR	NO	50%
335	5	PROTRUDING	TOP COAT	NONE	WET	DRILL	.323	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	HIGH	.318	DEBURR	NO	50%
336	5	PROTRUDING	TOP COAT	NONE	WET	DRILL	.323	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	HIGH	.318	DEBURR	NO	50%
337	5	PROTRUDING	TOP COAT	NONE	DRY	ABUS DRILL	.323	0.000	0.000	0.	0.	0.	TENSION	HIGH	LOW	.314	NONE	NO	50%
338	5	PROTRUDING	TOP COAT	NONE	DRY	ABUS DRILL	.323	0.000	0.000	0.	0.	0.	TENSION	HIGH	LOW	.314	NONE	NO	50%
339	5	PROTRUDING	TOP COAT	NONE	DRY	ABUS DRILL	.323	0.000	0.000	0.	0.	0.	TENSION	HIGH	LOW	.314	NONE	NO	50%
340	5	PROTRUDING	TOP COAT	NONE	DRY	ABUS DRILL	.323	0.000	0.000	0.	0.	0.	TENSION	HIGH	LOW	.314	NONE	NO	50%
341	5	PROTRUDING	BARE	SEALANT	WET	DRILL	.313	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	50%
342	5	PROTRUDING	BARE	SEALANT	WET	DRILL	.313	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	50%
343	5	PROTRUDING	BARE	SEALANT	WET	DRILL	.313	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	50%
344	5	PROTRUDING	BARE	SEALANT	WET	DRILL	.313	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	50%
345	5	PROTRUDING	BARE	NONE	DRY	ROUGHEN	.313	0.000	0.000	0.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	DEBURR	NO	50%
346	5	PROTRUDING	BARE	NONE	DRY	ROUGHEN	.313	0.000	0.000	0.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	DEBURR	NO	50%
347	5	PROTRUDING	BARE	NONE	DRY	ROUGHEN	.313	0.000	0.000	0.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	DEBURR	NO	50%
348	5	PROTRUDING	BARE	NONE	DRY	ROUGHEN	.313	0.000	0.000	0.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	DEBURR	NO	50%
349	5	COUNTERSNK	ALODINE	SEALANT	DRY	DRILL	.313	0.000	0.000	0.	0.	0.	SHEARCOIN	CLEARANCE	N/A	0.000	DEBURR	NO	50%
350	5	COUNTERSNK	ALODINE	SEALANT	DRY	DRILL	.313	0.000	0.000	0.	0.	0.	SHEARCOIN	CLEARANCE	N/A	0.000	DEBURR	NO	50%
351	5	COUNTERSNK	ALODINE	SEALANT	DRY	DRILL	.313	0.000	0.000	0.	0.	0.	SHEARCOIN	CLEARANCE	N/A	0.000	DEBURR	NO	50%
352	5	COUNTERSNK	ALODINE	SEALANT	DRY	DRILL	.313	0.000	0.000	0.	0.	0.	SHEARCOIN	CLEARANCE	N/A	0.000	DEBURR	NO	50%
353	5	COUNTERSNK	ALODINE	SEALANT	WET	DRILL	.302	.038	.137	0.	4.	0.	NONE	HIGH	N/A	0.000	NONE	NO	50%
354	5	COUNTERSNK	ALODINE	SEALANT	WET	DRILL	.302	.038	.137	0.	4.	0.	NONE	HIGH	N/A	0.000	NONE	NO	50%
355	5	COUNTERSNK	ALODINE	SEALANT	WET	DRILL	.302	.038	.137	0.	4.	0.	NONE	HIGH	N/A	0.000	NONE	NO	50%
356	5	COUNTERSNK	ALODINE	SEALANT	WET	DRILL	.302	.038	.137	0.	4.	0.	NONE	HIGH	N/A	0.000	NONE	NO	50%
357	5	COUNTERSNK	ALODINE	NONE	WET	DRILL-REAM	.323	.038	.137	0.	0.	0.	TENS-COIN	HIGH	LOW	.314	NONE	NO	50%
358	5	COUNTERSNK	ALODINE	NONE	WET	DRILL-REAM	.323	.038	.137	0.	0.	0.	TENS-COIN	HIGH	LOW	.314	NONE	NO	50%
359	5	COUNTERSNK	ALODINE	NONE	WET	DRILL-REAM	.323	.038	.137	0.	0.	0.	TENS-COIN	HIGH	LOW	.314	NONE	NO	50%
360	5	COUNTERSNK	ALODINE	NONE	WET	DRILL-REAM	.323	.038	.137	0.	0.	0.	TENS-COIN	HIGH	LOW	.314	NONE	NO	50%

SEQ NO.	DIAM. 16THS	HEAD STYLE	CORROSION PROTECTION	FAYING SURFACE	INSTAL-LATION	HOLE PREP.	HOLE DIAM	CSK OFST	CSK DEPTH	HOLE ANG.	CSK ANG	HOLE TAPER	COLLAR STYLE	INTER-FERENCE	COLE WORK	MANDREL SIZE	DE-BURR	REMO-VALS	LOAD TRNS
361	3	COUNTERSNK	PRIMED	SEALANT	DRY	ABUS DRILL	.190	.023	.037	0.	0.	0.	TENSION	HIGH	HIGH	.183	DEBURR	NO	100%
362	3	COUNTERSNK	PRIMED	SEALANT	DRY	ABUS DRILL	.190	.023	.037	0.	0.	0.	TENSION	HIGH	HIGH	.183	DEBURR	NO	100%
363	3	COUNTERSNK	PRIMED	SEALANT	DRY	ABUS DRILL	.190	.023	.037	0.	0.	0.	TENSION	HIGH	HIGH	.183	DEBURR	NO	100%
364	3	COUNTERSNK	PRIMED	SEALANT	DRY	ABUS DRILL	.190	.023	.037	0.	0.	0.	TENSION	HIGH	HIGH	.183	DEBURR	NO	100%
365	3	COUNTERSNK	BARE	ADHESIVE	DRY	DRILL	.182	.023	.074	0.	2.	2.	SOFT	HIGH	N/A	0.000	NONE	NO	100%
366	3	COUNTERSNK	BARE	ADHESIVE	DRY	DRILL	.182	.023	.074	0.	2.	2.	SOFT	HIGH	N/A	0.000	NONE	NO	100%
367	3	COUNTERSNK	BARE	ADHESIVE	DRY	DRILL	.182	.023	.074	0.	2.	2.	SOFT	HIGH	N/A	0.000	NONE	NO	100%
368	3	COUNTERSNK	BARE	ADHESIVE	DRY	DRILL	.182	.023	.074	0.	2.	2.	SOFT	HIGH	N/A	0.000	NONE	NO	100%
369	3	COUNTERSNK	PRIMED	NONE	DRY	DRILL	.191	0.000	0.000	0.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	DEBURR	NO	100%
370	3	COUNTERSNK	PRIMED	NONE	DRY	DRILL	.191	0.000	0.000	0.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	DEBURR	NO	100%
371	3	COUNTERSNK	PRIMED	NONE	DRY	DRILL	.191	0.000	0.000	0.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	DEBURR	NO	100%
372	3	COUNTERSNK	PRIMED	NONE	DRY	DRILL	.191	0.000	0.000	0.	0.	0.	SHEAR	CLEARANCE	N/A	0.000	DEBURR	NO	100%
373	3	COUNTERSNK	PRIMED	NONE	DRY	DRILL-REAM	.203	0.000	.111	0.	2.	0.	TENSION	CLEARANCE	LOW	.192	NONE	NO	100%
374	3	COUNTERSNK	PRIMED	NONE	DRY	DRILL-REAM	.203	0.000	.111	0.	2.	0.	TENSION	CLEARANCE	LOW	.192	NONE	NO	100%
375	3	COUNTERSNK	PRIMED	NONE	DRY	DRILL-REAM	.203	0.000	.111	0.	2.	0.	TENSION	CLEARANCE	LOW	.192	NONE	NO	100%
376	3	COUNTERSNK	PRIMED	NONE	DRY	DRILL-REAM	.203	0.000	.111	0.	2.	0.	TENSION	CLEARANCE	LOW	.192	NONE	NO	100%
377	3	COUNTERSNK	PRIMED	NONE	WET	ROUGHEN	.191	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	100%
378	3	COUNTERSNK	PRIMED	NONE	WET	ROUGHEN	.191	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	100%
379	3	COUNTERSNK	PRIMED	NONE	WET	ROUGHEN	.191	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	100%
380	3	COUNTERSNK	PRIMED	NONE	WET	ROUGHEN	.191	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	NONE	NO	100%
381	3	PROTRUDING	TOP COAT	NONE	WET	ROUGHEN	.191	0.000	0.000	0.	0.	0.	TENS-COIN	CLEARANCE	N/A	0.000	DEBURR	NO	100%
382	3	PROTRUDING	TOP COAT	NONE	WET	ROUGHEN	.191	0.000	0.000	0.	0.	0.	TENS-COIN	CLEARANCE	N/A	0.000	DEBURR	NO	100%
383	3	PROTRUDING	TOP COAT	NONE	WET	ROUGHEN	.191	0.000	0.000	0.	0.	0.	TENS-COIN	CLEARANCE	N/A	0.000	DEBURR	NO	100%
384	3	PROTRUDING	TOP COAT	NONE	WET	ROUGHEN	.191	0.000	0.000	0.	0.	0.	TENS-COIN	CLEARANCE	N/A	0.000	DEBURR	NO	100%
385	3	PROTRUDING	TOP COAT	SEALANT	DRY	ROUGHEN	.182	0.000	0.000	0.	0.	0.	SHEARCOIN	HIGH	N/A	0.000	NONE	NO	100%
386	3	PROTRUDING	TOP COAT	SEALANT	DRY	ROUGHEN	.182	0.000	0.000	0.	0.	0.	SHEARCOIN	HIGH	N/A	0.000	NONE	NO	100%
387	3	PROTRUDING	TOP COAT	SEALANT	DRY	ROUGHEN	.182	0.000	0.000	0.	0.	0.	SHEARCOIN	HIGH	N/A	0.000	NONE	NO	100%
388	3	PROTRUDING	TOP COAT	SEALANT	DRY	ROUGHEN	.182	0.000	0.000	0.	0.	0.	SHEARCOIN	HIGH	N/A	0.000	NONE	NO	100%
389	3	PROTRUDING	PRIMED	NONE	DRY	ABUS DRILL	.185	0.000	0.000	0.	0.	0.	SHEAR	LOW	N/A	0.000	NONE	NO	100%
390	3	PROTRUDING	PRIMED	NONE	DRY	ABUS DRILL	.185	0.000	0.000	0.	0.	0.	SHEAR	LOW	N/A	0.000	NONE	NO	100%
391	3	PROTRUDING	PRIMED	NONE	DRY	ABUS DRILL	.185	0.000	0.000	0.	0.	0.	SHEAR	LOW	N/A	0.000	NONE	NO	100%
392	3	PROTRUDING	PRIMED	NONE	DRY	ABUS DRILL	.185	0.000	0.000	0.	0.	0.	SHEAR	LOW	N/A	0.000	NONE	NO	100%
393	3	PROTRUDING	BARE	ADHESIVE	WET	DRILL	.185	0.000	0.000	0.	0.	0.	NONE	LOW	N/A	0.000	DEBURR	NO	100%
394	3	PROTRUDING	BARE	ADHESIVE	WET	DRILL	.185	0.000	0.000	0.	0.	0.	NONE	LOW	N/A	0.000	DEBURR	NO	100%
395	3	PROTRUDING	BARE	ADHESIVE	WET	DRILL	.185	0.000	0.000	0.	0.	0.	NONE	LOW	N/A	0.000	DEBURR	NO	100%
396	3	PROTRUDING	BARE	ADHESIVE	WET	DRILL	.185	0.000	0.000	0.	0.	0.	NONE	LOW	N/A	0.000	DEBURR	NO	100%
397	4	COUNTERSNK	BARE	SEALANT	WET	ABUS DRILL	.251	0.000	.110	0.	0.	0.	TENS-COIN	CLEARANCE	N/A	0.000	NONE	NO	100%
398	4	COUNTERSNK	BARE	SEALANT	WET	ABUS DRILL	.251	0.000	.110	0.	0.	0.	TENS-COIN	CLEARANCE	N/A	0.000	NONE	NO	100%
399	4	COUNTERSNK	BARE	SEALANT	WET	ABUS DRILL	.251	0.000	.110	0.	0.	0.	TENS-COIN	CLEARANCE	N/A	0.000	NONE	NO	100%
400	4	COUNTERSNK	BARE	SEALANT	WET	ABUS DRILL	.251	0.000	.110	0.	0.	0.	TENS-COIN	CLEARANCE	N/A	0.000	NONE	NO	100%

SEQ NO.	DIAM. 16THS	HEAD STYLE	CORROSION PROTECTION	FAYING SURFACE	INSTAL-LATION	HOLE PREP.	HOLE DIAM	CSK OFST	CSK DEPTH	HOLE ANG.	CSK ANG	HOLE TAPER	COLLAR STYLE	INTER-FERENCE	COLD WORK	MANDREL SIZE	DE-BURR	REMO-VALS	LOAD TRNS
401	3	PROTRUDING	PRIMED	SEALANT	WET	DRILL-REAM	.185	0.000	0.000	0.	0.	0.	TENSION	LOW	N/A	0.000	DEBURR	NO	100%
402	3	PROTRUDING	PRIMED	SEALANT	WET	DRILL-REAM	.185	0.000	0.000	0.	0.	0.	TENSION	LOW	N/A	0.000	DEBURR	NO	100%
403	3	PROTRUDING	PRIMED	SEALANT	WET	DRILL-REAM	.185	0.000	0.000	0.	0.	0.	TENSION	LOW	N/A	0.000	DEBURR	NO	100%
404	3	PROTRUDING	PRIMED	SEALANT	WET	DRILL-REAM	.185	0.000	0.000	0.	0.	0.	TENSION	LOW	N/A	0.000	DEBURR	NO	100%
405	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.257	0.000	0.000	0.	0.	0.	SHEAR	HIGH	HIGH	.251	DEBURR	NO	100%
406	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.257	0.000	0.000	0.	0.	0.	SHEAR	HIGH	HIGH	.251	DEBURR	NO	100%
407	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.257	0.000	0.000	0.	0.	0.	SHEAR	HIGH	HIGH	.251	DEBURR	NO	100%
408	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.257	0.000	0.000	0.	0.	0.	SHEAR	HIGH	HIGH	.251	DEBURR	NO	100%
409	4	COUNTERSNK	TOP COAT	NONE	WET	ROUGHEN	.249	.052	.165	0.	4.	0.	SHEAR	TRANSITION	N/A	0.000	NONE	NO	100%
410	4	COUNTERSNK	TOP COAT	NONE	WET	ROUGHEN	.249	.052	.165	0.	4.	0.	SHEAR	TRANSITION	N/A	0.000	NONE	NO	100%
411	4	COUNTERSNK	TOP COAT	NONE	WET	ROUGHEN	.249	.052	.165	0.	4.	0.	SHEAR	TRANSITION	N/A	0.000	NONE	NO	100%
412	4	COUNTERSNK	TOP COAT	NONE	WET	ROUGHEN	.249	.052	.165	0.	4.	0.	SHEAR	TRANSITION	N/A	0.000	NONE	NO	100%
413	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.249	0.000	.110	0.	2.	0.	NONE	TRANSITION	N/A	0.000	NONE	NO	100%
414	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.249	0.000	.110	0.	2.	0.	NONE	TRANSITION	N/A	0.000	NONE	NO	100%
415	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.249	0.000	.110	0.	2.	0.	NONE	TRANSITION	N/A	0.000	NONE	NO	100%
416	4	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.249	0.000	.110	0.	2.	0.	NONE	TRANSITION	N/A	0.000	NONE	NO	100%
417	4	COUNTERSNK	BARE	ADHESIVE	WET	ROUGHEN	.242	0.000	.055	0.	0.	0.	SHEAR	HIGH	N/A	0.000	NONE	NO	100%
418	4	COUNTERSNK	BARE	ADHESIVE	WET	ROUGHEN	.242	0.000	.055	0.	0.	0.	SHEAR	HIGH	N/A	0.000	NONE	NO	100%
419	4	COUNTERSNK	BARE	ADHESIVE	WET	ROUGHEN	.242	0.000	.055	0.	0.	0.	SHEAR	HIGH	N/A	0.000	NONE	NO	100%
420	4	COUNTERSNK	BARE	ADHESIVE	WET	ROUGHEN	.242	0.000	.055	0.	0.	0.	SHEAR	HIGH	N/A	0.000	NONE	NO	100%
421	4	PROTRUDING	BARE	SEALANT	DRY	DRILL	.251	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	DEBURR	NO	100%
422	4	PROTRUDING	BARE	SEALANT	DRY	DRILL	.251	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	DEBURR	NO	100%
423	4	PROTRUDING	BARE	SEALANT	DRY	DRILL	.251	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	DEBURR	NO	100%
424	4	PROTRUDING	BARE	SEALANT	DRY	DRILL	.251	0.000	0.000	0.	0.	0.	TENSION	CLEARANCE	N/A	0.000	DEBURR	NO	100%
425	4	PROTRUDING	BARE	SEALANT	WET	DRILL-REAM	.245	0.000	0.000	0.	0.	1.	SHEARCOIN	LOW	N/A	0.000	DEBURR	NO	100%
426	4	PROTRUDING	BARE	SEALANT	WET	DRILL-REAM	.245	0.000	0.000	0.	0.	1.	SHEARCOIN	LOW	N/A	0.000	DEBURR	NO	100%
427	4	PROTRUDING	BARE	SEALANT	WET	DRILL-REAM	.245	0.000	0.000	0.	0.	1.	SHEARCOIN	LOW	N/A	0.000	DEBURR	NO	100%
428	4	PROTRUDING	BARE	SEALANT	WET	DRILL-REAM	.245	0.000	0.000	0.	0.	1.	SHEARCOIN	LOW	N/A	0.000	DEBURR	NO	100%
429	4	PROTRUDING	TOP COAT	NONE	DRY	DRILL	.261	0.000	0.000	0.	0.	0.	SOFT	CLEARANCE	LOW	.255	NONE	NO	100%
430	4	PROTRUDING	TOP COAT	NONE	DRY	DRILL	.261	0.000	0.000	0.	0.	0.	SOFT	CLEARANCE	LOW	.255	NONE	NO	100%
431	4	PROTRUDING	TOP COAT	NONE	DRY	DRILL	.261	0.000	0.000	0.	0.	0.	SOFT	CLEARANCE	LOW	.255	NONE	NO	100%
432	4	PROTRUDING	TOP COAT	NONE	DRY	DRILL	.261	0.000	0.000	0.	0.	0.	SOFT	CLEARANCE	LOW	.255	NONE	NO	100%
433	4	PROTRUDING	PRIMED	SEALANT	WET	DRILL-REAM	.261	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	LOW	.254	NONE	NO	100%
434	4	PROTRUDING	PRIMED	SEALANT	WET	DRILL-REAM	.261	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	LOW	.254	NONE	NO	100%
435	4	PROTRUDING	PRIMED	SEALANT	WET	DRILL-REAM	.261	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	LOW	.254	NONE	NO	100%
436	4	PROTRUDING	PRIMED	SEALANT	WET	DRILL-REAM	.261	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	LOW	.254	NONE	NO	100%
437	4	PROTRUDING	PRIMED	NONE	WET	ABUS DRILL	.249	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	100%
438	4	PROTRUDING	PRIMED	NONE	WET	ABUS DRILL	.249	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	100%
439	4	PROTRUDING	PRIMED	NONE	WET	ABUS DRILL	.249	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	100%
440	4	PROTRUDING	PRIMED	NONE	WET	ABUS DRILL	.249	0.000	0.000	0.	0.	0.	TENSION	TRANSITION	N/A	0.000	NONE	NO	100%

SEQ NO.	DIAM. 16THS	HEAD STYLE	CORROSION PROTECTION	FAYING SURFACE	INSTAL-LATION	HOLE PREP.	HOLE DIAM	CSK DEST	CSK DEPTH	HOLE ANG.	CSK ANG	HOLE TAPER	COLLAR STYLE	INTER-FERENCE	COLD WORK	MANDREL SIZE	DE-BURR	REMO-VALS	LOAD TRNS
441	5	PROTRUDING	PRIMED	SEALANT	DRY	ROUGHEN	.302	0.000	0.000	0.	0.	0.	SOFT	HIGH	N/A	0.000	NONE	NO	100%
442	5	PROTRUDING	PRIMED	SEALANT	DRY	ROUGHEN	.302	0.000	0.000	0.	0.	0.	SOFT	HIGH	N/A	0.000	NONE	NO	100%
443	5	PROTRUDING	PRIMED	SEALANT	DRY	ROUGHEN	.302	0.000	0.000	0.	0.	0.	SOFT	HIGH	N/A	0.000	NONE	NO	100%
444	5	PROTRUDING	PRIMED	SEALANT	DRY	ROUGHEN	.302	0.000	0.000	0.	0.	0.	SOFT	HIGH	N/A	0.000	NONE	NO	100%
445	5	PROTRUDING	BARE	NONE	WET	DRILL	.323	0.000	0.000	0.	0.	0.	NONE	LOW	HIGH	.318	NONE	NO	100%
446	5	PROTRUDING	BARE	NONE	WET	DRILL	.323	0.000	0.000	0.	0.	0.	NONE	LOW	HIGH	.318	NONE	NO	100%
447	5	PROTRUDING	BARE	NONE	WET	DRILL	.323	0.000	0.000	0.	0.	0.	NONE	LOW	HIGH	.318	NONE	NO	100%
448	5	PROTRUDING	BARE	NONE	WET	DRILL	.323	0.000	0.000	0.	0.	0.	NONE	LOW	HIGH	.318	NONE	NO	100%
449	5	PROTRUDING	ALODINE	SEALANT	DRY	ROUGHEN	.323	0.000	0.000	0.	0.	0.	TENS-COIN	LOW	HIGH	.318	DEBURR	NO	100%
450	5	PROTRUDING	ALODINE	SEALANT	DRY	ROUGHEN	.323	0.000	0.000	0.	0.	0.	TENS-COIN	LOW	HIGH	.318	DEBURR	NO	100%
451	5	PROTRUDING	ALODINE	SEALANT	DRY	ROUGHEN	.323	0.000	0.000	0.	0.	0.	TENS-COIN	LOW	HIGH	.318	DEBURR	NO	100%
452	5	PROTRUDING	ALODINE	SEALANT	DRY	ROUGHEN	.323	0.000	0.000	0.	0.	0.	TENS-COIN	LOW	HIGH	.318	DEBURR	NO	100%
453	5	PROTRUDING	BARE	ADHESIVE	DRY	DRILL	.311	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	DEBURR	REMOVAL	100%
454	5	PROTRUDING	BARE	ADHESIVE	DRY	DRILL	.311	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	DEBURR	REMOVAL	100%
455	5	PROTRUDING	BARE	ADHESIVE	DRY	DRILL	.311	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	DEBURR	REMOVAL	100%
456	5	PROTRUDING	BARE	ADHESIVE	DRY	DRILL	.311	0.000	0.000	0.	0.	0.	SHEAR	TRANSITION	N/A	0.000	DEBURR	REMOVAL	100%
457	5	PROTRUDING	PRIMED	SEALANT	DRY	ABUS DRILL	.311	0.000	0.000	0.	0.	0.	TENSION	LOW	N/A	0.000	NONE	NO	100%
458	5	PROTRUDING	PRIMED	SEALANT	DRY	ABUS DRILL	.311	0.000	0.000	0.	0.	0.	TENSION	LOW	N/A	0.000	NONE	NO	100%
459	5	PROTRUDING	PRIMED	SEALANT	DRY	ABUS DRILL	.311	0.000	0.000	0.	0.	0.	TENSION	LOW	N/A	0.000	NONE	NO	100%
460	5	PROTRUDING	PRIMED	SEALANT	DRY	ABUS DRILL	.311	0.000	0.000	0.	0.	0.	TENSION	LOW	N/A	0.000	NONE	NO	100%
461	5	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL	.302	0.000	.063	0.	0.	0.	SHEAR	HIGH	N/A	0.000	DEBURR	NO	100%
462	5	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL	.302	0.000	.063	0.	0.	0.	SHEAR	HIGH	N/A	0.000	DEBURR	NO	100%
463	5	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL	.302	0.000	.063	0.	0.	0.	SHEAR	HIGH	N/A	0.000	DEBURR	NO	100%
464	5	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL	.302	0.000	.063	0.	0.	0.	SHEAR	HIGH	N/A	0.000	DEBURR	NO	100%
465	5	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.323	.075	.063	0.	0.	0.	SHEAR	TRANSITION	HIGH	.318	DEBURR	NO	100%
466	5	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.323	.075	.063	0.	0.	0.	SHEAR	TRANSITION	HIGH	.318	DEBURR	NO	100%
467	5	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.323	.075	.063	0.	0.	0.	SHEAR	TRANSITION	HIGH	.318	DEBURR	NO	100%
468	5	COUNTERSNK	PRIMED	SEALANT	DRY	DRILL-REAM	.323	.075	.063	0.	0.	0.	SHEAR	TRANSITION	HIGH	.318	DEBURR	NO	100%
469	5	COUNTERSNK	BARE	NONE	WET	DRILL-REAM	.311	0.000	.205	0.	4.	0.	TENSION	TRANSITION	N/A	0.000	DEBURR	NO	100%
470	5	COUNTERSNK	BARE	NONE	WET	DRILL-REAM	.311	0.000	.205	0.	4.	0.	TENSION	TRANSITION	N/A	0.000	DEBURR	NO	100%
471	5	COUNTERSNK	BARE	NONE	WET	DRILL-REAM	.311	0.000	.205	0.	4.	0.	TENSION	TRANSITION	N/A	0.000	DEBURR	NO	100%
472	5	COUNTERSNK	BARE	NONE	WET	DRILL-REAM	.311	0.000	.205	0.	4.	0.	TENSION	TRANSITION	N/A	0.000	DEBURR	NO	100%
473	5	COUNTERSNK	TOP COAT	SEALANT	DRY	DRILL-REAM	.323	0.000	.205	0.	4.	0.	TENSION	LOW	LOW	.315	DEBURR	NO	100%
474	5	COUNTERSNK	TOP COAT	SEALANT	DRY	DRILL-REAM	.323	0.000	.205	0.	4.	0.	TENSION	LOW	LOW	.315	DEBURR	NO	100%
475	5	COUNTERSNK	TOP COAT	SEALANT	DRY	DRILL-REAM	.323	0.000	.205	0.	4.	0.	TENSION	LOW	LOW	.315	DEBURR	NO	100%
476	5	COUNTERSNK	TOP COAT	SEALANT	DRY	DRILL-REAM	.323	0.000	.205	0.	4.	0.	TENSION	LOW	LOW	.315	DEBURR	NO	100%
477	5	COUNTERSNK	BARE	SEALANT	DRY	DRILL	.323	0.000	.137	0.	0.	0.	SHEARCOIN	HIGH	LOW	.314	DEBURR	NO	100%
478	5	COUNTERSNK	BARE	SEALANT	DRY	DRILL	.323	0.000	.137	0.	0.	0.	SHEARCOIN	HIGH	LOW	.314	DEBURR	NO	100%
479	5	COUNTERSNK	BARE	SEALANT	DRY	DRILL	.323	0.000	.137	0.	0.	0.	SHEARCOIN	HIGH	LOW	.314	DEBURR	NO	100%
480	5	COUNTERSNK	BARE	SEALANT	DRY	DRILL	.323	0.000	.137	0.	0.	0.	SHEARCOIN	HIGH	LOW	.314	DEBURR	NO	100%

APPENDIX C

TEST RESULTS

The computer listing which appears below shows 16 of the more significant test conditions and results for each of the 480 specimens.

SEQ NO.	GROSS STRESS PARAM. (KSI)	PRELOAD IN POUNDS	HOLE ROUGH-NESS (MICRO-IN)	HOLE TAPER ANGLE (ABS)	STR. DEV. (IN)	COLD WORK (IN)	E/D	FASTENER INTER-FERENCE (IN)	SHANK CONTACT	CSK DEPTH RATIO	GAP BETWEEN SHEETS (IN)	RELATIVE HUMIDITY	STRAIGHT. DIFFERENCE (IN)	THICKNESS/ DIAMETER RATIO	CYCLES TO FAILURE	FAIL CODE
1	28.41	788.	50.	0.00	-.0006	0.0000	3.92	-.0028	20.%	.42	-0.0000	55.%	.0002	1.36	13400	113
2	30.37	788.	45.	0.00	.0003	0.0000	3.91	-.0028	25.%	.46	-0.0000	55.%	.0014	1.27	10800	123
3	30.20	788.	65.	0.00	0.0000	0.0000	3.90	-.0028	10.%	.48	-0.0000	56.%	0.0000	1.28	12200	113
4	28.96	788.	40.	0.00	.0002	0.0000	3.93	-.0028	5.%	.48	-0.0000	56.%	.0002	1.33	13800	123
5	29.13	788.	165.	0.00	.0090	0.0000	3.99	.0052	100.%	.31	-0.0000	59.%	.0150	1.33	42300	123
6	28.77	788.	265.	0.00	.0085	0.0000	4.14	.0052	100.%	.31	-0.0000	59.%	.0005	1.34	42600	123
7	30.18	788.	170.	0.00	.0095	0.0000	4.08	.0052	90.%	.30	-0.0000	60.%	.0015	1.28	28200	113
8	28.34	788.	260.	.94	.0120	0.0000	4.15	.0057	80.%	.29	-0.0000	60.%	.0075	1.36	58900	113
9	28.92	1165.	110.	.26	-.0050	0.0000	3.89	-.0033	25.%	.12	-0.0000	59.%	0.0000	1.34	29000	127
10	30.03	1165.	80.	0.00	-.0055	0.0000	3.87	-.0028	25.%	.08	-0.0000	59.%	.0005	1.29	24300	114
11	30.04	1165.	185.	.25	-.0050	0.0000	3.85	-.0033	20.%	.05	-0.0000	61.%	0.0000	1.28	23700	114
12	30.20	1165.	50.	0.00	-.0060	0.0000	3.85	-.0028	20.%	.04	-0.0000	61.%	0.0000	1.28	29700	117
13	29.29	1165.	50.	0.00	0.0000	.0040	4.01	.0022	100.%	0.00	-0.0000	56.%	0.0000	1.32	243400	100
14	29.75	1165.	45.	0.00	0.0000	.0040	4.01	.0022	100.%	0.00	-0.0000	56.%	0.0000	1.30	458900	100
15	29.67	1165.	120.	0.00	.0005	.0040	3.99	.0022	100.%	0.00	-0.0000	56.%	0.0000	1.30	416500	100
16	29.19	1165.	110.	0.00	0.0000	.0040	4.00	.0022	100.%	0.00	-0.0000	56.%	0.0000	1.32	141000	100
17	28.06	1209.	250.	.44	.0080	0.0000	3.90	-.0038	10.%	0.00	-0.0000	68.%	.0100	1.38	27000	114
18	29.25	1209.	160.	.23	-.0028	0.0000	3.93	-.0023	10.%	0.00	-0.0000	68.%	.0101	1.32	34700	114
19	30.26	1209.	160.	.35	.0080	0.0000	3.90	-.0038	10.%	0.00	-0.0000	68.%	.0035	1.28	21600	114
20	29.99	1209.	130.	.47	.0012	0.0000	3.90	-.0018	10.%	0.00	-0.0000	68.%	.0048	1.29	25500	124
21	29.91	597.	250.	1.25	.0014	0.0000	3.91	-.0058	10.%	0.00	-0.0000	55.%	.0030	1.29	13800	124
22	28.67	597.	250.	.11	.0020	0.0000	3.92	-.0025	5.%	0.00	-0.0000	55.%	.0027	1.34	12900	114
23	30.12	597.	250.	.33	.0002	0.0000	3.97	-.0029	5.%	0.00	-0.0000	56.%	0.0000	1.28	12400	114
24	31.44	597.	250.	0.00	0.0000	0.0000	3.75	-.0035	10.%	0.00	-0.0000	56.%	.0030	1.20	11100	114
25	28.28	0.	140.	3.56	.0150	0.0000	4.00	.0092	100.%	0.00	-0.0000	64.%	0.0000	1.37	180300	100
26	30.12	0.	125.	3.32	.0150	0.0000	4.03	.0092	100.%	0.00	-0.0000	64.%	0.0000	1.28	182700	117
27	28.41	0.	120.	3.35	.0150	0.0000	4.33	.0087	100.%	0.00	-0.0000	65.%	0.0000	1.36	103400	124
28	28.13	0.	80.	3.55	.0150	0.0000	4.00	.0082	-0.%	0.00	-0.0000	66.%	0.0000	1.37	394000	100
29	30.01	2890.	80.	.36	0.0000	0.0000	2.93	-.0025	0.%	.67	-0.0000	64.%	0.0000	.97	6100	113
30	27.96	2890.	70.	.29	.0010	0.0000	2.92	-.0025	5.%	.62	-0.0000	64.%	0.0000	1.05	7000	123
31	30.03	2890.	50.	0.00	0.0000	0.0000	2.94	-.0023	5.%	.57	-0.0000	59.%	0.0000	.97	9600	113
32	29.91	2890.	65.	.35	.0005	0.0000	2.91	-.0025	10.%	.65	-0.0000	59.%	0.0000	.98	12600	114
33	29.63	2890.	60.	.23	.0120	.0035	2.90	-.0048	90.%	0.00	-0.0000	55.%	.0002	.99	24300	114
34	30.28	2890.	70.	.71	.0120	.0025	2.87	-.0038	100.%	0.00	-0.0000	59.%	.0025	.97	24100	114
35	28.84	2890.	150.	.23	.0130	.0025	2.33	-.0038	100.%	0.00	-0.0000	64.%	.0005	1.01	25300	114
36	29.29	2890.	140.	.92	.0130	.0020	2.90	-.0023	100.%	0.00	-0.0000	64.%	.0015	1.00	26900	124
37	30.16	1554.	300.	0.00	.0020	.0270	2.95	-.0043	100.%	.47	-0.0000	59.%	.0020	.97	48600	123
38	30.03	1554.	300.	.43	0.0000	.0270	2.94	-.0048	100.%	.45	-0.0000	59.%	0.0000	.98	40700	113
39	30.71	1554.	300.	.44	.0010	.0260	2.36	-.0038	90.%	.45	-0.0000	57.%	.0010	.95	79000	113
40	29.95	1554.	300.	1.29	0.0000	.0265	2.97	-.0048	90.%	.45	-0.0000	72.%	0.0000	.98	82400	113

SEQ NO.	GROSS STRESS PARAM. (KSI)	PRELOAD IN POUNDS	HOLE ROUGH-NESS (MICRO-IN)	HOLE TAPER ANGLE (ABS)	STR. DEV. (IN)	COLD WORK (IN)	E/D	FASTENER INTER-FERENCE (IN)	SHANK CONTACT	CSK DEPTH RATIO	GAP BETWEEN SHEETS (IN)	RELATIVE HUMIDITY	STRAIGHT. DIFFERENCE (IN)	THICKNESS/ DIAMETER RATIO	CYCLES TO FAILURE	FAIL CODE
41	28.05	1484.	150.	.22	.0020	0.0000	3.06	.0062	100.%	0.00	-0.0000	56.%	.0066	1.05	88400	112
42	30.43	1484.	85.	0.00	0.0000	0.0000	3.10	.0057	100.%	0.00	-0.0000	56.%	.0008	.96	200200	100
43	28.68	1484.	220.	0.00	.0040	0.0000	3.07	.0057	100.%	0.00	-0.0000	64.%	.0010	1.03	531200	100
44	29.33	1484.	130.	.23	0.0000	0.0000	3.07	.0052	100.%	0.00	-0.0000	60.%	.0018	1.00	232000	100
45	29.39	1554.	80.	.42	.0014	0.0000	3.12	.0054	100.%	0.00	-0.0000	64.%	.0014	.99	225500	121
46	28.80	1554.	250.	.43	0.0000	0.0000	3.10	.0050	100.%	0.00	-0.0000	55.%	0.0000	1.01	94300	100
47	29.65	1554.	250.	.12	.0014	0.0000	3.08	.0055	-0.%	0.00	-0.0000	55.%	.0026	.99	161000	100
48	28.69	1554.	250.	.11	.0012	0.0000	3.09	.0055	-0.%	0.00	-0.0000	59.%	.0008	1.02	114300	100
49	30.89	1554.	25.	.12	0.0000	.0070	3.03	-.0030	100.%	0.00	-0.0000	29.%	0.0000	.94	95300	124
50	30.33	1554.	65.	.24	0.0000	.0073	3.00	-.0028	100.%	0.00	-0.0000	40.%	0.0000	.96	59800	124
51	31.15	1554.	15.	0.00	0.0000	.0073	3.00	-.0023	100.%	0.00	-0.0000	64.%	.0020	.94	171900	117
52	29.57	1554.	25.	0.00	.0020	.0071	2.98	-.0023	100.%	0.00	-0.0000	40.%	0.0000	.99	121400	124
53	29.79	2456.	45.	0.00	0.0000	.0010	2.37	-.0013	100.%	0.00	-0.0000	68.%	0.0000	.98	38800	124
54	30.03	2456.	70.	.24	0.0000	.0015	2.37	-.0018	100.%	0.00	-0.0000	68.%	.0010	.98	28200	114
55	30.92	2456.	30.	.24	.0003	.0015	2.34	-.0018	100.%	0.00	-0.0000	51.%	.0012	.95	29300	124
56	29.71	2456.	30.	.23	.0005	.0015	2.95	-.0018	100.%	0.00	-0.0000	51.%	0.0000	.99	35000	114
57	30.09	3830.	70.	.47	.0035	0.0000	2.38	-.0023	5.%	0.00	-0.0000	55.%	.0040	.78	39300	124
58	28.03	3830.	100.	.66	.0020	0.0000	2.37	-.0028	5.%	0.00	-0.0000	55.%	.0010	.84	46700	114
59	29.89	3830.	140.	.23	.0010	0.0000	2.39	-.0038	5.%	0.00	-0.0000	55.%	.0003	.78	27500	124
60	28.77	3830.	70.	.45	.0030	0.0000	2.38	-.0043	0.%	0.00	-0.0000	55.%	.0020	.81	47900	124
61	31.35	5354.	250.	.37	0.0000	0.0000	2.88	-.0040	0.%	0.00	-0.0000	68.%	.0090	.75	20600	124
62	30.59	5354.	250.	.97	.0010	0.0000	2.87	-.0053	0.%	0.00	-0.0000	68.%	.0010	.76	17300	124
63	29.39	5354.	215.	.59	.0020	0.0000	2.37	-.0038	0.%	0.00	-0.0000	55.%	.0014	.80	26700	124
64	28.82	5354.	250.	0.00	.0022	0.0000	2.38	-.0053	0.%	0.00	-0.0000	55.%	.0021	.81	26000	114
65	29.19	5354.	240.	.69	.0040	0.0000	2.37	-.0048	5.%	0.00	-0.0000	55.%	.0025	.80	16200	114
66	30.33	5354.	160.	2.82	.0150	0.0000	2.35	-.0043	10.%	0.00	-0.0000	55.%	.0150	.77	20700	114
67	28.67	5354.	140.	3.39	.0100	0.0000	2.29	-.0078	-0.%	0.00	-0.0000	56.%	.0090	.81	23200	124
68	29.73	5354.	230.	3.97	.0050	0.0000	2.31	-.0088	-0.%	0.00	-0.0000	64.%	.0020	.79	19400	114
69	28.50	2726.	40.	.45	.0075	.0010	2.39	-.0013	100.%	0.00	-0.0000	55.%	.0010	.82	24300	114
70	30.35	2726.	65.	0.00	.0065	.0035	2.38	-.0023	100.%	0.00	-0.0000	55.%	.0005	.77	19200	124
71	30.05	2726.	170.	.24	.0040	.0030	2.38	-.0018	100.%	0.00	-0.0000	64.%	.0015	.78	19600	114
72	29.91	2726.	90.	0.00	.0045	.0040	2.38	-.0023	100.%	0.00	-0.0000	64.%	.0010	.79	21600	124
73	29.81	3830.	55.	0.00	0.0000	.0056	2.40	-.0013	100.%	.27	-0.0000	56.%	.0010	.78	96100	114
74	30.82	3830.	80.	.17	0.0000	.0063	2.42	-.0020	100.%	.29	-0.0000	56.%	.0010	.76	59600	113
75	29.35	3830.	65.	.32	.0009	.0060	2.40	-.0018	100.%	.28	-0.0000	69.%	.0009	.79	118800	114
76	28.79	3830.	55.	.16	.0050	.0062	2.40	-.0020	100.%	.28	-0.0000	64.%	.0040	.81	88600	113
77	30.45	2712.	160.	0.00	-.0030	.0060	2.37	-.0033	100.%	.23	-0.0000	64.%	.0055	.77	20000	124
78	28.73	2712.	225.	.57	.0020	.0020	2.33	-.0033	100.%	.21	-0.0000	64.%	.0010	.82	27700	124
79	28.88	2712.	210.	0.00	0.0000	.0010	2.22	-.0033	80.%	.25	-0.0000	61.%	.0030	.81	25900	113
80	30.07	2712.	280.	.30	.0030	.0040	2.34	-.0028	80.%	.21	-0.0000	61.%	0.0000	.78	28800	124

SEQ NO.	GROSS STRESS PARAM. (KSI)	PRELOAD IN POUNDS	HOLE ROUGH-NESS (MICRO-IN)	HOLE TAPER ANGLE (ABS)	STR. DEV. (IN)	COLD WORK (IN)	E/D	FASTENER INTER-FERENCE (IN)	SHANK CONTACT	CSK DEPTH RATIO	GAP BETWEEN SHEETS (IN)	RELATIVE HUMIDITY	STRAIGHT. DIFFERENCE (IN)	THICKNESS/ DIAMETER RATIO	CYCLES TO FAILURE	FAIL CODE
81	30.84	597.	130.	.82	.0030	0.0000	3.81	-.0058	10.%	.25	0.0000	40.%	0.0000	0.54	12300	224
82	30.17	597.	115.	.80	.0030	0.0000	3.82	-.0058	30.%	.24	0.0000	40.%	.0005	0.60	14400	224
83	30.14	597.	100.	.92	.0040	0.0000	3.80	-.0053	0.%	.23	0.0000	61.%	.0005	0.61	13700	114
84	30.46	597.	70.	1.06	.0030	0.0000	3.81	-.0048	20.%	.24	.0040	61.%	.0005	0.60	12800	214
85	30.18	1209.	225.	.81	.0035	0.0000	4.00	.0027	95.%	0.00	0.0000	47.%	.0050	0.63	57800	125
86	29.79	1209.	250.	.34	-.0030	0.0000	4.04	.0037	80.%	0.00	0.0000	47.%	.0040	0.67	152600	210
87	29.39	1209.	150.	.78	.0020	0.0000	4.03	.0027	-0.%	0.00	.0040	63.%	.0030	0.72	113600	200
88	30.51	1209.	225.	.70	-.0015	0.0000	4.01	.0022	-0.%	0.00	.0020	63.%	.0035	0.62	118100	206
89	29.74	0.	280.	.25	0.0000	0.0000	4.11	.0052	100.%	.22	.0110	40.%	.0040	0.73	67200	124
90	29.35	0.	150.	.13	-.0020	0.0000	4.15	.0057	35.%	.23	.0080	65.%	.0020	0.70	86800	214
91	29.92	0.	250.	.13	0.0000	0.0000	4.11	.0057	90.%	.21	.0060	64.%	.0015	0.64	87000	111
92	29.28	0.	185.	0.00	0.0000	0.0000	4.15	.0052	90.%	.24	.0090	56.%	.0015	0.71	91300	122
93	28.89	0.	55.	.55	-.0080	0.0000	4.09	.0077	50.%	0.00	.0070	40.%	.0005	0.75	58100	227
94	31.02	0.	50.	.83	-.0100	0.0000	4.08	.0067	25.%	0.00	.0060	49.%	.0005	0.57	22300	227
95	30.36	0.	225.	.81	-.0095	0.0000	4.05	.0047	30.%	0.00	.0055	61.%	.0035	0.62	29800	217
96	30.55	0.	150.	1.39	-.0170	0.0000	4.03	-.0028	30.%	0.00	.0085	63.%	.0040	0.62	13850	224
97	31.07	808.	200.	1.52	-.0010	0.0000	3.96	.0012	10.%	.47	.0030	52.%	.0020	0.57	11900	113
98	30.08	808.	200.	1.00	.0025	0.0000	3.97	-.0003	25.%	.43	.0060	40.%	.0075	0.67	15900	114
99	30.15	808.	180.	.15	-.0035	0.0000	3.96	-.0023	20.%	.46	.0020	62.%	.0060	0.65	13300	123
100	29.87	808.	170.	.69	.0015	0.0000	3.96	-.0003	-0.%	.40	.0080	62.%	.0025	0.71	13200	114
101	30.28	788.	180.	.45	0.0000	0.0000	3.91	-.0033	5.%	.49	0.0000	49.%	.0020	0.65	7100	113
102	29.74	788.	250.	.15	.0010	0.0000	3.89	-.0023	5.%	.50	0.0000	49.%	.0025	0.70	8600	114
103	30.59	788.	225.	.15	-.0030	0.0000	3.92	-.0023	5.%	.51	.0035	61.%	.0030	0.64	6300	123
104	30.33	788.	190.	.15	0.0000	0.0000	3.93	-.0033	30.%	.50	.0020	61.%	0.0000	0.69	7800	123
105	30.33	1165.	100.	.12	.0010	0.0000	3.95	-.0013	5.%	0.00	.0020	49.%	.0015	0.56	14900	124
106	29.18	1165.	65.	0.00	-.0005	0.0000	3.97	-.0008	10.%	0.00	.0010	49.%	.0020	0.65	29500	214
107	30.97	1165.	125.	0.00	.0005	0.0000	3.97	-.0008	10.%	0.00	.0010	64.%	.0005	0.50	12500	224
108	29.70	1165.	60.	0.00	.0015	0.0000	3.95	-.0008	10.%	0.00	.0010	64.%	.0029	0.61	15000	214
109	30.28	788.	120.	0.00	0.0000	.0040	3.95	-.0008	100.%	.47	.0015	52.%	0.0000	0.61	10950	123
110	29.04	788.	100.	0.00	.0025	.0040	3.94	-.0008	100.%	.46	.0015	52.%	.0005	0.72	12050	113
111	30.09	788.	80.	.30	.0010	.0025	3.97	.0007	100.%	.47	0.0000	63.%	0.0000	0.61	10250	113
112	31.20	788.	100.	.32	.0010	.0015	3.94	.0002	100.%	.48	0.0000	63.%	.0005	0.52	8450	123
113	30.60	1165.	55.	.59	-.0005	0.0000	4.01	.0037	50.%	0.00	.0020	28.%	.0010	0.58	22700	124
114	29.77	1165.	110.	.58	-.0020	0.0000	3.99	.0027	50.%	0.00	.0010	28.%	.0010	0.65	16900	214
115	30.12	1165.	135.	.70	.0010	0.0000	4.00	.0022	50.%	0.00	0.0000	56.%	.0010	0.61	19900	214
116	30.41	1165.	100.	.71	.0005	0.0000	4.00	.0032	75.%	0.00	0.0000	56.%	0.0000	0.59	13300	214
117	31.93	808.	100.	.74	-.0010	0.0000	4.10	.0082	95.%	0.00	.0070	49.%	.0055	0.46	110900	110
118	31.32	808.	180.	.73	-.0030	0.0000	4.09	.0082	95.%	0.00	.0035	48.%	.0072	0.49	122600	200
119	31.45	808.	180.	.51	-.0045	0.0000	4.09	.0067	90.%	0.00	.0055	54.%	.0100	0.49	115600	113
120	30.99	808.	160.	.84	-.0025	0.0000	4.08	.0087	90.%	0.00	.0070	54.%	.0030	0.53	87500	123

SEQ NO.	GROSS STRESS PARAM. (KSI)	PRELOAD IN POUNDS	HOLE ROUGH-NESS (MICRO-IN)	HOLE TAPER ANGLE (ABS)	STR. DEV. (IN)	COLD WORK (IN)	E/D	FASTENER INTER-FERENCE (IN)	SHANK CONTACT	CSK DEPTH RATIO	GAP BETWEEN SHEETS (IN)	RELATIVE HUMIDITY	STRAIGHT. DIFFERENCE (IN)	THICKNESS/ DIAMETER RATIO	CYCLES TO FAILURE	FAIL CODE
121	29.40	1165.	100.	0.00	.0005	0.0000	3.99	.0002	50.%	0.00	.0020	49.%	.0010	2.66	26700	214
122	30.27	1165.	105.	.12	-.0010	0.0000	4.00	-.0003	20.%	0.00	.0010	49.%	.0015	2.58	19700	124
123	30.33	1165.	120.	0.00	-.0020	0.0000	4.01	.0002	20.%	0.00	0.0000	50.%	.0005	2.57	18800	124
124	30.19	1165.	100.	0.00	-.0005	0.0000	3.98	.0002	20.%	0.00	0.0000	50.%	.0010	2.59	17300	124
125	29.85	1165.	280.	0.00	-.0040	.0005	3.92	-.0008	50.%	0.00	.0030	49.%	.0120	2.61	14900	215
126	30.05	1165.	250.	0.00	.0270	0.0000	3.85	-.0008	0.%	0.00	.0050	49.%	.0080	2.59	11800	224
127	30.02	1165.	130.	.77	.0095	.0013	3.85	.0020	100.%	0.00	.0020	63.%	.0075	2.58	13250	214
128	28.85	1165.	150.	.45	-.0015	.0040	3.82	.0012	100.%	0.00	.0045	63.%	.0240	2.70	13100	214
129	30.00	788.	120.	1.17	.0045	0.0000	3.87	-.0018	15.%	0.00	.0020	40.%	.0020	2.61	13700	215
130	30.72	788.	120.	.60	.0015	0.0000	3.96	.0007	70.%	0.00	.0025	40.%	.0015	2.55	20400	124
131	30.59	788.	110.	.71	.0040	0.0000	3.94	.0002	20.%	0.00	.0010	63.%	.0035	2.56	18100	215
132	28.80	788.	200.	.90	.0040	0.0000	3.91	-.0008	50.%	0.00	.0025	61.%	.0010	2.72	16200	124
133	30.16	788.	70.	0.00	.0010	.0040	3.98	.0012	100.%	0.00	.0010	52.%	.0010	2.59	89600	214
134	29.51	788.	70.	0.00	0.0000	.0045	3.97	.0012	100.%	0.00	.0015	48.%	.0020	2.64	73500	100
135	30.46	788.	100.	0.00	.0010	.0040	3.75	-.0118	-0.%	0.00	0.0000	43.%	.0010	2.56	139900	100
136	30.52	788.	80.	.12	0.0000	.0050	3.75	-.0113	100.%	0.00	0.0000	43.%	0.0000	2.57	122100	215
137	30.55	1165.	90.	.12	0.0000	0.0000	3.98	.0017	75.%	0.00	.0035	49.%	.0010	2.58	19000	214
138	29.31	1165.	150.	.23	0.0000	0.0000	3.97	.0012	90.%	0.00	.0025	49.%	.0010	2.67	20900	214
139	29.86	1165.	80.	.06	-.0007	0.0000	4.01	.0015	40.%	0.00	.0010	63.%	.0003	2.61	17700	124
140	29.80	1165.	130.	.12	0.0000	0.0000	4.00	.0017	50.%	0.00	.0010	63.%	.0015	2.62	15450	214
141	30.60	788.	120.	.12	.0010	.0080	3.88	-.0033	80.%	0.00	.0070	61.%	.0055	2.58	19500	225
142	29.61	788.	260.	.11	.0010	.0085	3.88	-.0033	50.%	0.00	.0120	61.%	.0060	2.70	28000	114
143	29.69	788.	180.	.23	0.0000	.0065	3.90	-.0018	100.%	0.00	.0160	64.%	.0030	2.71	14300	214
144	30.56	788.	135.	.35	-.0065	.0050	3.90	-.0013	100.%	0.00	.0120	64.%	.0020	2.62	13700	114
145	29.37	2890.	250.	.22	-.0045	0.0000	3.05	.0017	35.%	0.00	0.0000	53.%	.0035	2.06	25600	214
146	29.48	2890.	250.	.11	.0025	0.0000	3.07	.0032	25.%	0.00	0.0000	53.%	.0015	2.05	28100	124
147	30.30	2890.	260.	.35	-.0010	0.0000	3.06	.0042	90.%	0.00	0.0000	65.%	0.0000	2.00	27500	124
148	29.36	2890.	280.	.33	0.0000	0.0000	3.04	.0032	95.%	0.00	0.0000	65.%	0.0000	2.08	66200	214
149	29.75	2456.	120.	0.00	.0010	.0060	2.99	-.0023	95.%	0.00	0.0000	66.%	.0025	2.02	36050	215
150	29.71	2456.	250.	0.00	-.0035	.0060	2.98	-.0023	95.%	0.00	0.0000	66.%	.0015	2.03	33000	214
151	30.55	2456.	250.	0.00	.0020	.0035	2.97	-.0023	100.%	0.00	.0020	56.%	0.0000	1.98	31300	125
152	30.23	2456.	245.	0.00	.0030	.0040	2.87	-.0143	100.%	0.00	.0040	56.%	.0015	2.00	28300	124
153	29.15	2890.	160.	0.00	.0070	.0130	3.02	.0007	35.%	0.00	0.0000	66.%	.0125	2.06	71100	125
154	30.36	2890.	140.	.12	.0025	.0130	3.00	.0002	100.%	0.00	0.0000	55.%	.0035	1.98	50400	214
155	29.57	2890.	100.	0.00	-.0060	.0135	3.02	-.0003	100.%	0.00	.0010	55.%	.0060	2.04	50400	227
156	29.92	2890.	120.	0.00	.0050	.0115	3.01	-.0003	100.%	0.00	.0020	55.%	.0020	2.02	37400	215
157	30.24	1554.	150.	.35	.0065	0.0000	2.98	-.0038	10.%	0.00	0.0000	66.%	.0020	1.97	8200	214
158	30.11	1554.	110.	1.05	.0110	0.0000	2.91	-.0058	5.%	0.00	0.0000	66.%	.0025	1.98	9800	214
159	29.54	1554.	160.	1.03	.0140	0.0000	2.88	-.0058	5.%	0.00	0.0000	56.%	.0055	2.02	9300	214
160	29.72	1554.	220.	.59	.0080	0.0000	2.89	-.0073	10.%	0.00	0.0000	56.%	.0020	2.00	11600	114

SEQ NO.	GROSS STRESS PARAM. (KSI)	PRELOAD IN POUNDS	HOLE ROUGH-NESS (MICRO-IN)	HOLE TAPER ANGLE (ABS)	STR. DEV. (IN)	COLD WORK (IN)	E/D	FASTENER INTER-FERENCE (IN)	SHANK CONTACT	CSK DEPTH RATIO	GAP BETWEEN SHEETS (IN)	RELATIVE HUMIDITY	STRAIGHT. DIFFERENCE (IN)	THICKNESS/ DIAMETER RATIO	CYCLES TO FAILURE	FAIL CODE
161	30.01	1554.	180.	.59	.0010	0.0000	2.96	.0052	10.%	0.00	0.0000	66.%	.0030	1.95	17200	125
162	30.93	1554.	150.	.61	.0040	0.0000	3.06	.0052	90.%	0.00	0.0000	66.%	.0030	1.89	48700	114
163	29.72	1554.	165.	.23	0.0000	0.0000	3.03	.0037	30.%	0.00	.0015	49.%	.0020	1.98	42800	224
164	29.51	1554.	170.	.81	.0030	0.0000	3.04	.0052	30.%	0.00	.0020	49.%	.0040	1.99	44300	215
165	29.03	0.	120.	0.00	0.0000	0.0000	3.09	.0057	90.%	0.00	0.0000	55.%	.0005	2.07	118900	217
166	29.84	0.	120.	0.00	.0015	0.0000	3.08	.0057	95.%	0.00	0.0000	55.%	.0010	2.02	75100	214
167	29.93	0.	60.	0.00	0.0000	0.0000	3.09	.0057	100.%	0.00	.0020	63.%	.0010	2.02	85800	113
168	29.85	0.	60.	0.00	.0005	0.0000	3.09	.0057	100.%	0.00	.0020	63.%	.0005	2.03	79300	113
169	30.76	1554.	210.	1.90	.0220	0.0000	2.78	-.0113	5.%	0.00	.0010	28.%	.0010	1.94	11700	124
170	29.09	1554.	280.	1.69	.0180	0.0000	2.80	-.0098	-0.%	0.00	.0020	28.%	.0030	2.05	14500	214
171	29.86	1554.	280.	3.22	.0180	0.0000	2.77	-.0103	5.%	0.00	.0020	56.%	.0060	2.00	12700	214
172	30.02	1554.	280.	.93	.0200	0.0000	2.80	-.0083	0.%	0.00	.0020	56.%	.0040	1.99	11600	124
173	29.89	1208.	160.	.80	.0035	0.0000	3.03	.0032	85.%	0.00	0.0000	65.%	.0010	2.02	34500	215
174	29.18	1208.	140.	.45	-.0050	0.0000	3.02	.0037	80.%	0.00	0.0000	66.%	.0080	2.06	29900	214
175	28.69	1208.	140.	.44	0.0000	0.0000	3.02	.0027	100.%	0.00	.0010	55.%	.0020	2.10	40100	215
176	29.62	1208.	180.	.34	.0050	0.0000	3.03	.0032	100.%	0.00	.0010	55.%	.0030	2.04	23400	125
177	28.71	1208.	280.	0.00	.0055	.0080	2.97	-.0013	35.%	0.00	0.0000	66.%	.0015	2.10	25200	224
178	30.68	1208.	160.	0.00	.0055	.0085	2.97	-.0013	100.%	0.00	0.0000	66.%	.0055	1.96	79150	200
179	30.18	1208.	150.	.12	.0090	.0080	2.98	-.0008	90.%	0.00	.0010	60.%	.0120	2.00	29100	124
180	29.27	1208.	165.	.11	.0040	.0095	2.99	-.0008	70.%	0.00	.0020	49.%	.0025	2.06	18700	224
181	29.72	1484.	160.	.52	-.0025	0.0000	3.07	.0007	50.%	.24	.0040	61.%	.0020	2.00	53800	224
182	29.76	1484.	280.	1.45	.0070	0.0000	2.98	-.0018	50.%	.24	.0005	61.%	.0025	1.98	56400	214
183	29.75	1484.	170.	.65	.0015	0.0000	3.04	.0022	30.%	.23	0.0000	56.%	.0050	1.99	15000	114
184	30.32	1484.	90.	.13	-.0015	0.0000	3.06	.0032	20.%	.24	.0020	56.%	.0015	1.95	18300	113
185	29.72	2890.	280.	.11	-.0010	0.0000	3.07	.0052	100.%	0.00	0.0000	53.%	0.0000	2.03	112000	217
186	29.37	2890.	300.	.22	-.0030	0.0000	3.09	.0037	100.%	0.00	0.0000	53.%	.0005	2.05	112800	200
187	29.02	2890.	180.	.11	-.0018	0.0000	3.10	.0052	100.%	0.00	.0020	64.%	.0009	2.08	131000	200
188	29.13	2890.	140.	.11	.0010	0.0000	3.09	.0052	-0.%	0.00	.0020	64.%	.0030	2.07	102200	200
189	29.67	1484.	125.	0.00	.0043	.0075	2.95	-.0033	90.%	.15	0.0000	61.%	.0108	2.03	30800	225
190	29.65	1484.	130.	0.00	-.0038	.0040	2.95	-.0033	85.%	.11	0.0000	61.%	.0028	2.03	14100	214
191	29.76	1484.	120.	.50	.0055	.0045	2.83	-.0158	100.%	.12	.0010	57.%	.0075	2.02	29800	115
192	28.90	1484.	130.	.35	-.0015	.0055	2.82	-.0148	70.%	.12	.0030	57.%	.0005	2.09	17600	115
193	29.77	2890.	80.	.06	.0010	0.0000	2.99	-.0025	10.%	0.00	.0010	39.%	0.0000	2.00	17900	215
194	29.93	2890.	80.	0.00	-.0010	0.0000	2.98	-.0023	10.%	0.00	.0010	39.%	0.0000	1.99	17300	224
195	30.87	2890.	100.	0.00	0.0000	0.0000	2.99	-.0023	10.%	0.00	.0020	39.%	0.0000	1.93	33300	214
196	30.60	2890.	35.	.06	0.0000	0.0000	2.99	-.0025	10.%	0.00	.0020	39.%	.0010	1.95	16300	214
197	29.60	2456.	250.	.29	-.0030	0.0000	2.93	-.0043	10.%	.44	0.0000	61.%	.0030	2.03	11900	124
198	29.36	2456.	200.	1.41	.0065	0.0000	2.93	-.0053	10.%	.41	0.0000	61.%	.0095	2.06	16500	214
199	30.25	2456.	160.	0.00	-.0060	0.0000	2.97	-.0023	15.%	.45	.0010	60.%	.0100	1.99	9900	123
200	29.75	2456.	120.	0.00	-.0035	0.0000	2.95	-.0023	15.%	.42	.0020	60.%	.0005	2.03	11700	124

SEQ NO.	GROSS STRESS PARAM. (KSI)	PRELOAD IN POUNDS	HOLE ROUGH-NESS (MICRO-IN)	HOLE TAPER ANGLE (ABS)	STR. DEV. (IN)	COLD WORK (IN)	E/D	FASTENER INTER-FERENCE (IN)	SHANK CONTACT	CSK DEPTH RATIO	GAP BETWEEN SHEETS (IN)	RELATIVE HUMIDITY	STRAIGHT. DIFFERENCE (IN)	THICKNESS/ DIAMETER RATIO	CYCLES TO FAILURE	FAIL CODE
201	30.27	2890.	110.	.13	.0030	.0040	2.98	-.0018	80.%	.23	.0025	61.%	.0015	1.97	20500	124
202	29.29	2890.	180.	0.00	.0050	.0045	2.98	-.0013	80.%	.24	.0060	53.%	.0060	2.05	22500	124
203	29.20	2890.	225.	.06	.0050	.0048	2.95	-.0025	80.%	.25	.0030	50.%	.0050	2.05	17500	124
204	30.04	2890.	250.	0.00	-.0010	.0050	2.95	-.0023	80.%	.24	.0050	50.%	.0010	2.00	16000	124
205	30.16	1554.	50.	.13	-.0035	.0060	2.92	-.0048	95.%	.24	0.0000	53.%	.0020	1.97	18900	214
206	30.79	1554.	250.	0.00	-.0017	.0150	3.10	-.0043	90.%	.21	0.0000	53.%	.0048	1.93	38400	114
207	29.96	1554.	250.	0.00	.0090	.0140	2.94	-.0053	100.%	.24	.0060	49.%	.0065	2.00	38000	113
208	30.49	1554.	250.	.06	-.0040	.0198	2.95	-.0050	100.%	.22	.0100	49.%	.0050	1.99	62400	123
209	30.16	1554.	150.	1.78	.0065	0.0000	3.04	.0057	95.%	.45	0.0000	55.%	0.0000	2.00	89300	206
210	29.46	1554.	120.	1.45	.0060	0.0000	3.04	.0057	95.%	.45	0.0000	55.%	0.0000	2.04	52200	114
211	29.71	1554.	220.	1.60	.0055	0.0000	3.04	.0052	80.%	.46	.0030	49.%	0.0000	2.04	60100	115
212	29.88	1554.	95.	1.39	.0040	0.0000	3.04	.0050	70.%	.45	.0020	49.%	.0020	2.02	55600	121
213	28.37	3830.	145.	.22	-.0020	0.0000	2.38	-.0053	0.%	0.00	.0030	52.%	.0020	1.70	15400	124
214	29.83	3830.	240.	.56	.0050	0.0000	2.36	-.0048	0.%	0.00	.0090	52.%	.0050	1.65	10000	124
215	29.19	3830.	250.	.33	-.0045	0.0000	2.37	-.0048	20.%	0.00	.0030	63.%	.0085	1.66	12300	214
216	29.86	3830.	230.	.80	.0020	0.0000	2.34	-.0058	10.%	0.00	.0030	63.%	.0035	1.62	10000	124
217	30.39	5354.	260.	.12	-.0015	0.0000	2.39	-.0048	0.%	0.00	0.0000	56.%	.0015	1.56	19100	224
218	28.97	5354.	120.	.79	-.0010	0.0000	2.36	-.0058	0.%	0.00	0.0000	56.%	0.0000	1.63	16400	124
219	30.05	5354.	125.	.35	.0010	0.0000	2.39	-.0038	5.%	0.00	0.0000	49.%	.0020	1.57	12000	124
220	30.18	5354.	135.	.24	-.0010	0.0000	2.38	-.0043	5.%	0.00	0.0000	52.%	.0010	1.56	17400	124
221	29.85	0.	135.	0.00	.0025	.0040	2.37	-.0033	100.%	0.00	0.0000	52.%	.0005	1.61	9200	124
222	29.18	0.	120.	.11	-.0025	.0065	2.36	-.0038	100.%	0.00	.0060	52.%	.0005	1.67	9600	124
223	29.76	0.	130.	.11	.0045	.0030	2.38	-.0028	100.%	0.00	.0010	63.%	.0075	1.62	8300	124
224	29.54	0.	130.	.11	.0070	.0025	2.37	-.0028	100.%	0.00	.0010	63.%	.0045	1.63	8200	124
225	28.97	2712.	120.	.17	.0300	0.0000	2.28	-.0025	2.%	0.00	0.0000	52.%	0.0000	1.64	15300	214
226	30.08	2712.	100.	0.00	.0300	0.0000	2.28	-.0033	5.%	0.00	0.0000	52.%	0.0000	1.58	12400	224
227	30.77	2712.	80.	0.00	.0250	0.0000	2.29	-.0033	10.%	0.00	.0010	63.%	.0050	1.55	11700	224
228	29.13	2712.	80.	.11	.0320	0.0000	2.28	-.0028	10.%	0.00	.0020	63.%	.0020	1.64	16900	124
229	29.50	3830.	120.	.34	.0040	0.0000	2.37	-.0038	0.%	0.00	0.0000	48.%	.0020	1.64	9100	214
230	30.24	3830.	125.	.46	.0010	0.0000	2.36	-.0043	10.%	0.00	0.0000	48.%	.0060	1.60	10200	215
231	30.34	3830.	135.	.58	.0010	0.0000	2.36	-.0048	5.%	0.00	.0010	59.%	.0030	1.59	11800	215
232	28.93	3830.	140.	.44	.0085	0.0000	2.34	-.0053	5.%	0.00	.0010	59.%	.0085	1.67	14900	124
233	30.02	2726.	270.	0.00	.0115	.0060	2.33	-.0043	100.%	0.00	.0030	63.%	.0025	1.63	15400	214
234	29.43	2726.	280.	0.00	.0110	.0040	2.34	-.0043	100.%	0.00	.0030	63.%	.0010	1.66	15400	124
235	29.17	2726.	280.	0.00	.0135	.0060	2.34	-.0053	99.%	0.00	.0040	60.%	.0040	1.68	23700	114
236	29.13	2726.	275.	0.00	.0110	.0050	2.33	-.0053	99.%	0.00	.0030	60.%	.0015	1.67	19100	124
237	29.23	5354.	180.	0.00	.0045	0.0000	2.34	-.0053	10.%	0.00	.0010	56.%	0.0000	1.63	23900	114
238	30.42	5354.	180.	.12	.0025	0.0000	2.39	-.0038	10.%	0.00	0.0000	56.%	.0005	1.56	19000	124
239	29.20	5354.	250.	.45	-.0015	0.0000	2.38	-.0043	0.%	0.00	0.0000	56.%	.0005	1.63	20300	124
240	30.03	5354.	230.	.23	.0010	0.0000	2.38	-.0043	0.%	0.00	0.0000	70.%	0.0000	1.58	20800	212

SEQ NO.	GROSS STRESS PARAM. (KSI)	PRELOAD IN POUNDS	HOLE ROUGH-NESS (MICRO-IN)	HOLE TAPER ANGLE (ABS)	STR. DEV. (IN)	COLD WORK (IN)	E/D	FASTENER INTER-FERENCE (IN)	SHANK CONTACT	CSK DEPTH RATIO	GAP BETWEEN SHEETS (IN)	RELATIVE HUMIDITY	STRAIGHT. DIFFERENCE (IN)	THICKNESS/ DIAMETER RATIO	CYCLES TO FAILURE	FAIL CODE
241	30.62	3830.	120.	.24	-.0075	0.0000	2.33	-.0063	100.%	0.00	.0010	52.%	.0120	1.54	8500	214
242	29.65	3830.	140.	0.00	.0060	.0030	2.33	-.0053	100.%	0.00	.0030	52.%	.0010	1.59	16400	124
243	30.00	3830.	100.	0.00	.0010	.0020	2.36	-.0043	100.%	0.00	0.0000	59.%	.0025	1.56	20100	125
244	28.86	3830.	90.	0.00	.0050	.0050	2.34	-.0043	100.%	0.00	.0040	59.%	.0060	1.64	32000	124
245	28.21	0.	85.	.11	.0010	0.0000	2.48	.0082	100.%	0.00	.0020	56.%	.0030	1.70	67200	225
246	29.25	0.	130.	.23	.0005	0.0000	2.45	.0077	100.%	0.00	.0020	56.%	.0025	1.64	79900	214
247	30.58	0.	60.	.12	-.0023	0.0000	2.47	.0082	70.%	0.00	.0020	60.%	.0023	1.57	41100	214
248	30.59	0.	130.	.18	.0030	0.0000	2.48	.0080	70.%	0.00	.0020	60.%	.0043	1.57	27400	215
249	29.46	2712.	140.	0.00	.0020	.0065	2.35	-.0053	50.%	.85	0.0000	49.%	.0010	1.64	3200	123
250	30.02	2712.	165.	0.00	.0060	.0070	2.35	-.0043	70.%	.85	0.0000	49.%	.0020	1.60	3800	123
251	29.42	2712.	130.	0.00	.0035	.0060	2.36	-.0043	100.%	.80	.0030	62.%	.0005	1.65	6600	122
252	29.55	2712.	155.	.19	.0075	.0060	2.35	-.0048	100.%	.83	.0030	62.%	.0040	1.64	3800	122
253	30.43	3830.	135.	.78	.0045	0.0000	2.35	-.0043	5.%	.83	.0040	56.%	.0065	1.60	5800	124
254	30.50	3830.	130.	1.14	.0110	0.0000	2.31	-.0033	10.%	.82	.0060	56.%	.0090	1.51	6000	124
255	36.57	3830.	80.	.19	.0065	0.0000	2.40	-.0028	10.%	.85	.0020	50.%	.0065	1.63	1300	124
256	30.09	3830.	165.	1.32	.0090	0.0000	2.35	-.0028	10.%	.83	.0070	50.%	.0010	1.62	3800	124
257	28.93	3830.	60.	.11	.0010	0.0000	2.40	-.0028	10.%	0.00	0.0000	56.%	.0005	1.63	19200	214
258	29.62	3830.	80.	.12	0.0000	0.0000	2.40	-.0028	5.%	0.00	0.0000	56.%	0.0000	1.59	15200	214
259	29.89	3830.	80.	0.00	0.0000	0.0000	2.40	-.0023	5.%	0.00	0.0000	70.%	.0010	1.58	21700	124
260	29.52	3830.	70.	0.00	.0005	0.0000	2.40	-.0023	5.%	0.00	0.0000	70.%	0.0000	1.60	25000	124
261	29.70	5354.	65.	0.00	0.0000	.0050	2.38	-.0013	100.%	.81	0.0000	57.%	0.0000	1.57	21200	122
262	29.62	5354.	75.	0.00	0.0000	.0060	2.38	-.0013	100.%	.82	0.0000	57.%	0.0000	1.58	18200	122
263	30.14	5354.	55.	0.00	0.0000	.0065	2.38	-.0023	100.%	.85	0.0000	56.%	0.0000	1.56	14800	122
264	29.76	5354.	65.	0.00	0.0000	.0065	2.39	-.0023	100.%	.84	0.0000	56.%	0.0000	1.57	14700	122
265	30.04	5354.	250.	2.14	.0100	0.0000	2.38	-.0003	20.%	.25	.0010	47.%	.0125	1.59	10900	124
266	29.69	5354.	250.	1.45	.0075	0.0000	2.41	.0032	50.%	.25	.0010	47.%	.0085	1.61	25100	124
267	28.62	5354.	250.	1.40	.0040	0.0000	2.41	.0042	90.%	.27	.0020	63.%	.0030	1.67	48100	124
268	29.05	5354.	250.	1.30	.0030	0.0000	2.43	.0037	70.%	.27	.0010	63.%	.0030	1.64	32300	124
269	29.72	5354.	70.	.13	-.0010	0.0000	2.37	-.0048	0.%	.25	.0060	56.%	.0020	1.62	15500	214
270	29.51	5354.	160.	.13	-.0017	0.0000	2.37	-.0058	-0.%	.27	.0100	56.%	.0007	1.64	12800	214
271	29.55	5354.	130.	.79	-.0030	0.0000	2.34	-.0053	0.%	.28	.0020	63.%	.0005	1.62	13800	224
272	28.47	5354.	140.	.50	.0025	0.0000	2.33	-.0083	0.%	.27	.0030	63.%	.0005	1.68	16100	224
273	29.75	5180.	120.	.16	.0025	0.0000	2.35	-.0038	-0.%	.55	.0020	56.%	.0025	1.62	12000	214
274	29.51	5180.	140.	.46	-.0030	0.0000	2.37	-.0038	-0.%	.54	.0100	56.%	0.0000	1.65	12100	124
275	28.96	5180.	70.	.15	-.0015	0.0000	2.38	-.0048	15.%	.55	.0060	56.%	.0015	1.67	12400	114
276	29.87	5180.	135.	.47	.0010	0.0000	2.38	-.0038	10.%	.56	.0030	56.%	.0017	1.61	9000	124
277	30.96	5180.	150.	0.00	0.0000	0.0000	2.39	-.0033	30.%	.51	0.0000	61.%	.0040	1.54	10200	113
278	30.88	5180.	160.	.57	-.0010	0.0000	2.40	-.0023	20.%	.59	0.0000	61.%	.0045	1.54	10600	215
279	31.10	5180.	100.	.51	0.0000	0.0000	2.38	-.0038	20.%	.51	.0010	59.%	0.0000	1.54	13900	214
280	28.90	5180.	110.	.46	0.0000	0.0000	2.37	-.0048	30.%	.55	.0030	59.%	0.0000	1.66	21200	114

SEQ NO.	GROSS STRESS PARAM. (KSI)	PRELOAD IN POUNDS	HOLE ROUGH-NESS (MICRO-IN)	HOLE TAPER ANGLE (ABS)	STR. DEV. (IN)	COLD WORK (IN)	E/D	FASTENER INTER-FERENCE (IN)	SHANK CONTACT	CSK DEPTH RATIO	GAP BETWEEN SHEETS (IN)	RELATIVE HUMIDITY	STRAIGHT. DIFFERENCE (IN)	THICKNESS/ DIAMETER RATIO	CYCLES TO FAILURE	FAIL CODE
281	30.87	788.	220.	.13	.0050	0.0000	4.08	.0057	100.%	.17	.0010	29.%	.0020	2.60	38200	215
282	28.71	788.	120.	0.00	-.0050	0.0000	4.10	.0052	100.%	.14	.0030	29.%	.0015	2.62	20500	215
283	30.35	788.	90.	.26	.0035	0.0000	4.12	.0052	100.%	.13	.0010	29.%	0.0000	2.47	38000	215
284	29.95	788.	150.	.13	.0015	0.0000	4.11	.0057	100.%	.14	.0020	29.%	.0020	2.55	22400	215
285	28.49	1209.	130.	.99	.0035	0.0000	3.91	.0002	10.%	.21	.0020	53.%	.0010	2.74	15700	214
286	29.43	1209.	125.	1.00	.0045	0.0000	3.33	.0002	10.%	.22	.0010	53.%	0.0000	2.74	16400	215
287	28.92	1209.	120.	1.02	.0045	0.0000	4.01	.0002	10.%	.22	.0010	53.%	0.0000	2.69	10200	215
288	29.85	1209.	90.	1.04	.0050	0.0000	3.93	.0002	20.%	.23	.0010	53.%	.0010	2.64	13300	214
289	28.75	788.	90.	.11	.0240	0.0000	3.94	.0027	95.%	0.00	0.0000	57.%	.0030	2.67	8700	214
290	31.63	788.	85.	.24	.0260	0.0000	3.97	.0032	95.%	0.00	0.0000	57.%	.0005	2.58	12600	214
291	30.20	788.	170.	.35	.0280	0.0000	3.95	.0027	95.%	0.00	0.0000	57.%	.0010	2.61	10400	215
292	30.72	788.	170.	.12	.0250	0.0000	3.95	.0027	95.%	0.00	0.0000	57.%	.0010	2.55	8900	215
293	27.72	1165.	140.	.14	-.0015	.0015	3.90	-.0003	100.%	.42	.0040	64.%	.0050	2.79	6000	215
294	30.09	1165.	240.	.29	.0005	.0015	3.91	.0012	100.%	.47	.0070	64.%	.0035	2.67	6100	215
295	28.35	1165.	230.	.29	.0010	.0020	3.96	.0012	100.%	.44	.0020	64.%	.0015	2.72	5800	215
296	30.20	1165.	240.	.15	0.0000	.0025	3.94	.0007	100.%	.45	.0010	64.%	.0010	2.67	6000	215
297	29.55	1165.	170.	0.00	.0160	.0025	3.86	-.0018	100.%	0.00	.0020	53.%	.0090	2.72	9900	214
298	28.27	1165.	240.	0.00	.0135	.0045	3.83	-.0018	100.%	0.00	.0020	53.%	.0035	2.73	6900	215
299	28.77	1165.	250.	.11	.0140	.0045	3.77	-.0023	100.%	0.00	.0080	53.%	.0025	2.82	10200	214
300	29.85	1165.	270.	0.00	.0110	.0020	3.82	-.0028	50.%	0.00	.0060	53.%	.0350	2.68	6900	215
301	30.26	808.	20.	0.00	.0005	.0020	3.98	.0012	100.%	0.00	.0009	63.%	.0005	2.60	8100	215
302	31.13	808.	60.	0.00	.0005	.0030	3.95	.0002	100.%	0.00	0.0000	63.%	0.0000	2.56	8400	215
303	30.85	808.	40.	.36	.0005	.0042	3.34	-.0015	100.%	0.00	.0020	65.%	0.0000	2.60	10400	215
304	30.24	808.	50.	.12	.0005	.0045	3.34	-.0013	100.%	0.00	.0020	65.%	0.0000	2.63	8400	214
305	30.09	597.	35.	0.00	.0010	0.0000	4.12	.0052	100.%	0.00	.0020	53.%	0.0000	2.71	17400	215
306	30.53	597.	35.	0.00	.0005	0.0000	4.08	.0052	100.%	0.00	.0020	53.%	.0005	2.65	10500	215
307	30.12	597.	40.	0.00	.0020	0.0000	4.11	.0052	100.%	0.00	.0040	53.%	.0010	2.68	17500	215
308	29.87	597.	35.	0.00	.0015	0.0000	4.11	.0052	100.%	0.00	.0040	53.%	0.0000	2.71	11900	215
309	30.26	2890.	140.	.52	.0140	0.0000	2.94	-.0033	0.%	.22	.0020	57.%	.0005	1.97	12900	215
310	28.50	2890.	140.	.12	.0125	0.0000	2.95	-.0038	0.%	.20	.0030	57.%	.0015	2.09	23400	214
311	29.66	2890.	140.	.26	.0150	0.0000	2.37	-.0023	5.%	.22	0.0000	52.%	.0020	2.03	13000	215
312	30.22	2890.	140.	.26	.0130	0.0000	2.95	-.0033	5.%	.22	0.0000	52.%	.0020	2.02	11600	215
313	30.18	0.	150.	.17	.0200	.0095	2.92	-.0018	80.%	.65	0.0000	57.%	0.0000	2.02	11000	214
314	29.99	0.	150.	.16	.0200	.0095	2.93	-.0028	90.%	.65	0.0000	57.%	.0010	2.06	14900	214
315	28.75	0.	140.	.16	.0185	.0080	2.91	-.0028	50.%	.64	.0015	52.%	.0025	2.06	8300	215
316	29.53	0.	140.	.49	.0170	.0095	2.91	-.0038	50.%	.66	.0020	52.%	.0030	2.06	26400	214
317	28.08	1554.	150.	.07	.0110	.0072	2.99	-.0040	30.%	.42	0.0000	63.%	0.0000	2.06	27100	214
318	30.03	1554.	150.	.30	.0030	.0005	2.95	-.0053	20.%	.48	0.0000	63.%	.0080	1.99	11300	214
319	29.47	1554.	100.	.14	.0030	.0065	2.96	-.0038	100.%	.43	.0005	65.%	0.0000	2.03	20800	215
320	30.80	1554.	140.	.14	.0050	.0070	2.97	-.0038	100.%	.46	.0005	65.%	.0010	2.04	22500	215

SEQ NO.	GROSS STRESS PARAM. (KSI)	PRELOAD IN POUNDS	HOLE ROUGH-NESS (MICRO-IN)	HOLE TAPER ANGLE (ABS)	STR. DEV. (IN)	COLD WORK (IN)	E/D	FASTENER INTER-FERENCE (IN)	SHANK CONTACT	CSK DEPTH RATIO	GAP BETWEEN SHEETS (IN)	RELATIVE HUMIDITY	STRAIGHT. DIFFERENCE (IN)	THICKNESS/ DIAMETER RATIO	CYCLES TO FAILURE	FAIL CODE
321	29.71	1554.	20.	0.00	.0005	0.0000	2.99	-.0013	0.%	0.00	0.0000	57.%	0.0000	2.00	14500	214
322	30.37	1554.	20.	0.00	.0005	0.0000	3.01	-.0013	0.%	0.00	0.0000	57.%	0.0000	2.01	11800	214
323	30.08	1554.	25.	0.00	.0005	0.0000	3.00	-.0013	0.%	0.00	0.0000	57.%	.0010	1.99	13500	214
324	29.65	1554.	20.	0.00	.0010	0.0000	2.99	-.0013	0.%	0.00	0.0000	57.%	0.0000	1.99	12900	214
325	29.93	2890.	200.	0.00	.0005	0.0000	2.97	-.0033	0.%	0.00	.0030	63.%	.0010	1.99	12600	214
326	30.43	2890.	35.	0.00	.0005	0.0000	2.98	-.0033	0.%	0.00	.0015	63.%	0.0000	2.00	19300	214
327	28.82	2890.	45.	0.00	.0005	0.0000	2.97	-.0033	0.%	0.00	.0020	63.%	.0005	2.01	12500	214
328	28.67	2890.	50.	0.00	-.0010	0.0000	2.97	-.0033	0.%	0.00	.0030	63.%	0.0000	2.02	12400	214
329	28.54	1208.	25.	0.00	0.0000	0.0000	3.02	-.0003	0.%	0.00	.0030	55.%	0.0000	2.09	10800	214
330	29.09	1208.	25.	0.00	.0005	0.0000	3.01	-.0003	0.%	0.00	.0040	55.%	.0005	2.00	10600	214
331	29.45	1208.	65.	0.00	.0055	0.0000	2.38	-.0003	70.%	0.00	0.0000	62.%	.0015	1.99	8400	214
332	28.45	1208.	50.	.11	-.0070	0.0000	3.00	-.0008	50.%	0.00	.0020	62.%	.0045	2.04	8700	214
333	28.47	3830.	115.	0.00	-.0010	.0055	2.38	-.0043	100.%	0.00	.0020	55.%	.0005	1.59	14600	214
334	29.93	3830.	200.	0.00	-.0005	.0065	2.37	-.0043	100.%	0.00	.0020	63.%	.0005	1.58	18100	214
335	29.83	3830.	130.	0.00	.0015	.0070	2.39	-.0043	100.%	0.00	.0020	55.%	.0015	1.57	17500	214
336	28.30	3830.	100.	0.00	-.0005	.0075	2.38	-.0043	100.%	0.00	.0020	55.%	.0015	1.65	25100	214
337	28.94	5354.	100.	.06	.0095	.0022	2.37	-.0020	40.%	0.00	.0050	57.%	.0055	1.60	10300	214
338	29.99	5354.	145.	.12	.0025	.0010	2.37	-.0018	30.%	0.00	.0080	57.%	.0015	1.59	11000	214
339	29.89	5354.	140.	.06	.0060	.0013	2.35	-.0015	50.%	0.00	.0060	55.%	.0030	1.56	6700	214
340	28.03	5354.	145.	0.00	.0060	.0010	2.37	-.0013	55.%	0.00	.0090	55.%	0.0000	1.68	9600	214
341	30.24	5354.	220.	.57	.0040	0.0000	2.38	-.0048	0.%	0.00	0.0000	57.%	.0005	1.63	14100	214
342	30.18	5354.	120.	.24	.0040	0.0000	2.39	-.0033	0.%	0.00	0.0000	57.%	.0015	1.55	11100	214
343	30.31	5354.	120.	.03	.0010	0.0000	2.39	-.0028	0.%	0.00	0.0000	57.%	.0020	1.63	14700	214
344	29.27	5354.	170.	.23	.0030	0.0000	2.38	-.0033	0.%	0.00	0.0000	57.%	.0010	1.63	20300	214
345	29.29	3830.	65.	.59	-.0040	0.0000	2.29	-.0058	0.%	0.00	.0020	63.%	.0015	1.57	12300	214
346	29.15	3830.	85.	.59	0.0000	0.0000	2.37	-.0048	0.%	0.00	.0020	63.%	.0040	1.57	12000	214
347	28.61	3830.	220.	.56	.0070	0.0000	2.38	-.0048	5.%	0.00	.0020	62.%	.0055	1.64	18200	214
348	30.74	3830.	150.	.70	.0035	0.0000	2.36	-.0053	0.%	0.00	.0010	62.%	.0010	1.59	62900	214
349	28.60	2726.	60.	.23	-.0100	0.0000	2.33	-.0053	0.%	0.00	0.0000	57.%	.0025	1.64	15500	214
350	29.83	2726.	110.	0.00	.0115	0.0000	2.40	-.0053	0.%	0.00	0.0000	57.%	0.0000	1.59	24500	214
351	30.63	2726.	80.	.24	.0120	0.0000	2.34	-.0053	5.%	0.00	.0005	62.%	.0020	1.56	18600	214
352	30.67	2726.	40.	.46	.0150	0.0000	2.39	-.0053	5.%	0.00	.0005	62.%	.0030	1.60	21400	214
353	30.56	0.	125.	.35	.0020	0.0000	2.47	.0057	80.%	.55	.0020	63.%	.0020	1.48	4200	214
354	29.47	0.	125.	.47	.0025	0.0000	2.45	.0062	80.%	.52	.0010	52.%	.0025	1.58	6900	214
355	30.20	0.	140.	.31	.0110	0.0000	2.37	.0057	80.%	.53	.0010	52.%	0.0000	1.59	7400	214
356	30.35	0.	130.	.31	.0050	0.0000	2.45	.0057	80.%	.53	.0020	52.%	.0070	1.60	11700	215
357	28.75	5180.	50.	0.00	.0010	.0050	2.37	-.0013	100.%	.47	.0060	57.%	.0005	1.60	21500	215
358	30.82	5180.	50.	.15	0.0000	.0060	2.38	-.0018	100.%	.51	.0090	57.%	0.0000	1.58	15100	215
359	30.72	5180.	30.	0.00	-.0005	.0067	2.39	-.0023	100.%	.51	0.0000	65.%	0.0000	1.53	19300	216
360	28.88	5180.	60.	.08	.0005	.0073	2.39	-.0015	100.%	.48	0.0000	65.%	.0005	1.58	18800	216

SEQ NO.	GROSS STRESS PARAM. (KSI)	PRELOAD IN POUNDS	HOLE ROUGH-NESS (MICRO-IN)	HOLE TAPER ANGLE (ABS)	STR. DEV. (IN)	COLD WORK (IN)	E/D	FASTENER INTER-FERENCE (IN)	SHANK CONTACT	CSK DEPTH RATIO	GAP BETWEEN SHEETS (IN)	RELATIVE HUMIDITY	STRAIGHT. DIFFERENCE (IN)	THICKNESS/ DIAMETER RATIO	CYCLES TO FAILURE	FAIL CODE
361	28.45	1165.	32.	0.00	.0050	.0035	3.73	.0002	100.%	.14	0.0000	48.%	.0050	4.20	5300	224
362	30.36	1165.	100.	0.00	.0025	.0160	4.02	.0032	100.%	.14	0.0000	48.%	.0015	3.98	8700	20
363	29.85	1165.	110.	0.00	.0025	.0150	4.01	.0022	100.%	.16	0.0000	48.%	.0045	4.03	8200	20
364	28.60	1165.	130.	0.00	.0040	.0175	4.00	.0022	100.%	.14	0.0000	48.%	.0010	4.18	11700	20
365	28.19	597.	85.	2.30	.0085	0.0000	3.89	.0072	90.%	.25	0.0000	48.%	.0015	4.05	8600	224
366	30.14	597.	90.	2.45	.0070	0.0000	3.92	.0072	50.%	.29	0.0000	48.%	.0005	3.90	8200	20
367	31.49	597.	85.	3.36	.0070	0.0000	3.92	.0117	95.%	.31	0.0000	48.%	0.0000	3.96	6500	224
368	30.43	597.	100.	2.60	.0085	0.0000	3.93	.0057	90.%	.28	0.0000	48.%	.0010	3.85	5900	20
369	30.01	788.	130.	0.00	0.0000	0.0000	3.87	-.0058	0.%	0.00	0.0000	53.%	0.0000	3.90	4800	224
370	30.30	788.	60.	0.00	-.0010	0.0000	3.84	-.0058	0.%	0.00	0.0000	53.%	.0005	3.89	5100	224
371	30.28	788.	175.	.12	0.0000	0.0000	3.85	-.0053	0.%	0.00	0.0000	53.%	0.0000	3.91	4600	224
372	29.83	788.	75.	0.00	.0010	0.0000	3.84	-.0058	0.%	0.00	0.0000	53.%	.0010	3.91	5800	224
373	30.01	1165.	40.	0.00	.0005	.0030	3.95	-.0008	100.%	.45	0.0000	48.%	.0005	3.98	5900	224
374	30.37	1165.	60.	0.00	0.0000	.0040	3.91	-.0018	100.%	.47	0.0000	48.%	0.0000	3.87	6400	224
375	30.01	1165.	45.	.08	0.0000	.0023	3.94	0.0000	100.%	.48	0.0000	48.%	0.0000	3.90	5700	224
376	29.89	1165.	25.	.15	0.0000	.0035	3.91	-.0013	100.%	.45	0.0000	48.%	0.0000	3.86	7000	224
377	29.43	1165.	150.	0.00	-.0030	0.0000	4.31	.0032	100.%	0.00	.0100	48.%	.0010	4.09	3400	20
378	30.82	1165.	160.	.23	.0030	0.0000	3.99	.0002	85.%	0.00	.0130	48.%	0.0000	4.01	5700	224
379	30.16	1165.	150.	.46	0.0000	0.0000	4.04	.0012	90.%	0.00	.0125	48.%	0.0000	4.11	5300	20
380	28.94	1165.	85.	.44	.0060	0.0000	3.92	.0002	80.%	0.00	.0095	48.%	.0050	4.15	6500	224
381	29.93	1209.	200.	0.00	.0035	0.0000	3.95	-.0028	30.%	0.00	0.0000	48.%	.0005	4.06	5100	224
382	30.68	1209.	190.	0.00	.0015	0.0000	3.95	-.0018	30.%	0.00	0.0000	48.%	.0020	3.96	4900	224
383	31.69	1209.	195.	.36	.0045	0.0000	3.98	.0017	95.%	0.00	0.0000	48.%	.0040	3.87	4100	224
384	30.93	1209.	195.	.47	-.0030	0.0000	3.99	.0022	95.%	0.00	0.0000	48.%	.0050	3.84	4000	224
385	30.32	808.	250.	.35	.0020	0.0000	4.06	.0037	100.%	0.00	0.0000	48.%	.0060	4.01	6700	20
386	28.24	808.	250.	0.00	.0025	0.0000	4.08	.0022	100.%	0.00	0.0000	48.%	.0010	4.28	3800	20
387	29.03	808.	250.	.33	-.0055	0.0000	4.04	.0037	100.%	0.00	.0060	48.%	.0020	4.24	5300	20
388	30.24	808.	250.	.23	-.0010	0.0000	4.12	.0052	100.%	0.00	.0030	48.%	.0020	4.08	6000	20
389	29.65	788.	95.	1.93	-.0010	0.0000	3.84	-.0013	70.%	0.00	0.0000	53.%	.0005	4.07	9600	20
390	28.60	788.	100.	0.00	-.0020	0.0000	4.12	.0052	100.%	0.00	0.0000	53.%	.0020	4.08	14400	20
391	29.39	788.	90.	0.00	-.0010	0.0000	4.12	.0052	100.%	0.00	0.0000	47.%	.0030	4.06	8400	20
392	29.99	788.	200.	0.00	0.0000	0.0000	4.12	.0052	100.%	0.00	0.0000	47.%	.0005	3.91	15000	20
393	30.90	0.	260.	.48	.0005	0.0000	3.90	-.0008	40.%	0.00	0.0000	48.%	.0025	3.98	2200	10
394	27.85	0.	270.	.56	.0045	0.0000	3.92	-.0003	50.%	0.00	0.0000	49.%	.0035	4.10	1900	10
395	29.41	0.	175.	.57	.0005	0.0000	3.87	-.0003	40.%	0.00	0.0000	49.%	.0010	4.05	1300	20
396	29.33	0.	150.	.78	-.0020	0.0000	3.85	-.0023	30.%	0.00	0.0000	49.%	.0010	4.08	1600	10
397	28.96	1371.	40.	0.00	0.0000	0.0000	4.03	-.0022	100.%	0.00	0.0000	48.%	0.0000	4.02	4900	20
398	30.87	1371.	40.	0.00	-.0005	0.0000	4.06	-.0032	100.%	0.00	0.0000	48.%	.0005	3.99	6500	20
399	26.04	1371.	55.	0.00	0.0000	0.0000	4.03	-.0022	100.%	0.00	0.0000	48.%	0.0000	4.04	7100	20
400	27.41	1371.	60.	0.00	.0005	0.0000	4.03	-.0022	100.%	0.00	0.0000	48.%	.0005	4.00	9100	20

SEQ NO.	GROSS STRESS PARAM. (KSI)	PRELOAD IN POUNDS	HOLE ROUGH-NESS (MICRO-IN)	HOLE TAPER ANGLE (ABS)	STR. DEV. (IN)	COLD WORK (IN)	E/D	FASTENER INTER-FERENCE (IN)	SHANK CONTACT	CSK DEPTH RATIO	GAP BETWEEN SHEETS (IN)	RELATIVE HUMIDITY	STRAIGHT. DIFFERENCE (IN)	THICKNESS/ DIAMETER RATIO	CYCLES TO FAILURE	FAIL CODE
401	28.68	2088.	185.	.14	-.0010	0.0000	3.04	-.0032	100.%	.42	0.0000	45.%	.0015	3.13	5600	224
402	28.88	2088.	210.	.28	-.0030	0.0000	3.03	-.0027	100.%	.41	0.0000	45.%	.0040	3.06	7700	224
403	29.89	2088.	200.	.30	0.0000	0.0000	3.03	-.0027	100.%	.47	0.0000	45.%	.0035	3.07	5900	224
404	30.05	2088.	225.	.30	.0015	0.0000	3.02	-.0007	90.%	.47	0.0000	45.%	.0010	3.04	4100	224
405	30.52	1554.	25.	.06	0.0000	.0082	3.00	0.0000	100.%	0.00	0.0000	49.%	0.0000	3.01	7700	224
406	29.04	1554.	30.	.11	0.0000	.0090	2.99	.0002	100.%	0.00	0.0000	49.%	0.0000	3.06	12300	224
407	29.75	1554.	30.	0.00	.0005	.0100	2.99	-.0003	100.%	0.00	0.0000	49.%	0.0000	3.12	9600	224
408	29.99	1554.	30.	0.00	.0005	.0100	2.99	-.0003	100.%	0.00	0.0000	49.%	.0005	3.07	9000	224
409	28.48	1554.	275.	1.17	.0010	0.0000	3.02	-.0038	30.%	.62	.0015	45.%	.0030	3.01	8200	224
410	29.77	1554.	300.	0.00	.0025	0.0000	3.01	-.0003	50.%	.63	.0035	45.%	.0025	3.10	9200	224
411	29.89	1554.	250.	.16	.0015	0.0000	2.98	-.0008	40.%	.63	.0010	45.%	.0020	3.03	7300	224
412	30.50	1554.	325.	.16	.0050	0.0000	3.00	-.0018	35.%	.62	.0045	45.%	0.0000	3.02	6300	224
413	30.48	0.	30.	0.00	.0010	0.0000	2.94	-.0003	100.%	.47	.0040	39.%	.0010	3.03	4400	224
414	29.49	0.	85.	.14	0.0000	0.0000	3.01	-.0008	100.%	.44	.0060	39.%	0.0000	3.15	5400	224
415	29.43	0.	25.	0.00	0.0000	0.0000	3.02	-.0003	100.%	.45	.0040	39.%	0.0000	3.12	4500	224
416	28.94	0.	20.	0.00	.0005	0.0000	2.85	-.0003	100.%	.44	.0090	39.%	0.0000	3.20	5400	224
417	28.92	1554.	320.	.13	.0050	0.0000	3.11	.0072	100.%	.22	0.0000	52.%	.0020	2.99	65000	225
418	30.26	1554.	320.	.13	.0020	0.0000	3.10	.0072	95.%	.22	0.0000	47.%	.0035	2.87	15300	224
419	32.14	1554.	150.	.83	.0035	0.0000	3.10	.0097	95.%	.25	0.0000	47.%	.0010	2.87	35600	224
420	31.49	1554.	175.	0.00	.0035	0.0000	3.10	.0057	95.%	.23	0.0000	47.%	.0010	3.00	45200	224
421	29.89	2890.	150.	0.00	-.0010	0.0000	2.96	-.0023	30.%	0.00	0.0000	49.%	.0005	3.03	7100	224
422	29.83	2890.	155.	.11	-.0025	0.0000	2.96	-.0028	30.%	0.00	0.0000	49.%	0.0000	3.05	5900	224
423	29.29	2890.	155.	0.00	-.0015	0.0000	2.98	-.0013	30.%	0.00	0.0000	49.%	0.0000	3.09	6400	224
424	29.71	2890.	115.	.12	-.0010	0.0000	2.98	-.0018	30.%	0.00	0.0000	49.%	0.0000	2.98	5600	224
425	29.81	1484.	45.	1.74	.0010	0.0000	2.85	-.0008	50.%	0.00	.0010	53.%	.0010	3.00	3900	224
426	28.01	1484.	35.	1.70	.0005	0.0000	2.87	-.0008	50.%	0.00	.0010	53.%	.0010	3.04	5200	224
427	28.47	1484.	40.	1.74	.0015	0.0000	2.54	-.0008	50.%	0.00	.0010	53.%	.0005	3.00	4800	224
428	29.63	1484.	90.	1.50	.0010	0.0000	2.93	-.0008	50.%	0.00	.0010	53.%	0.0000	2.98	4700	224
429	28.41	1208.	105.	.06	-.0010	.0077	2.94	-.0045	100.%	0.00	.0010	45.%	.0005	3.16	14000	224
430	30.56	1208.	105.	0.00	-.0010	.0090	2.94	-.0053	100.%	0.00	.0010	45.%	0.0000	3.02	12200	224
431	28.92	1208.	105.	0.00	.0010	.0100	2.93	-.0053	100.%	0.00	.0010	45.%	0.0000	3.07	13100	224
432	29.93	1208.	95.	0.00	0.0000	.0090	2.93	-.0043	100.%	0.00	.0010	45.%	0.0000	2.99	7000	224
433	30.93	2890.	30.	0.00	0.0000	.0080	2.94	-.0033	100.%	0.00	0.0000	45.%	.0025	3.02	3600	224
434	30.65	2890.	20.	0.00	0.0000	.0080	2.96	-.0033	100.%	0.00	0.0000	45.%	0.0000	3.03	3700	224
435	30.08	2890.	15.	.11	0.0000	.0075	2.96	-.0038	100.%	0.00	0.0000	45.%	0.0000	3.07	4900	224
436	31.00	2890.	25.	0.00	0.0000	.0090	2.96	-.0033	100.%	0.00	0.0000	45.%	.0035	3.01	5100	224
437	29.35	2890.	300.	.46	.0015	0.0000	2.96	-.0033	30.%	0.00	.0035	45.%	.0010	3.02	4200	224
438	28.88	2890.	350.	.11	.0050	0.0000	2.96	-.0048	30.%	0.00	.0015	45.%	.0035	3.05	7200	224
439	28.63	2890.	200.	.81	.0085	0.0000	2.78	.0002	30.%	0.00	.0010	45.%	.0015	2.96	6500	224
440	28.43	2890.	175.	.45	-.0090	0.0000	3.01	.0007	30.%	0.00	.0010	45.%	.0055	3.07	7200	224

SEQ NO.	GROSS STRESS PARAM. (KSI)	PRELOAD IN POUNDS	HOLE ROUGH-NESS (MICRO-IN)	HOLE TAPER ANGLE (ABS)	STR. DEV. (IN)	COLD WORK (IN)	E/D	FASTENER INTER-FERENCE (IN)	SHANK CONTACT	CSK DEPTH RATIO	GAP BETWEEN SHEETS (IN)	RELATIVE HUMIDITY	STRAIGHT. DIFFERENCE (IN)	THICKNESS/ DIAMETER RATIO	CYCLES TO FAILURE	FAIL CODE
441	30.60	2712.	175.	0.00	.0060	0.0000	2.33	.0097	100.%	0.00	.0100	43.%	.0045	2.49	7600	224
442	30.52	2712.	175.	.11	.0060	0.0000	2.47	.0082	100.%	0.00	.0100	43.%	.0045	2.45	20600	224
443	28.79	2712.	175.	.11	.0035	0.0000	2.48	.0092	100.%	0.00	.0100	55.%	.0010	2.59	16800	224
444	29.99	2712.	185.	0.00	.0040	0.0000	2.48	.0087	100.%	0.00	.0100	55.%	.0005	2.48	45900	224
445	30.39	0.	115.	.12	-.0035	.0010	2.31	-.0038	100.%	0.00	0.0000	55.%	.0020	2.34	4300	224
446	29.51	0.	125.	0.00	-.0025	.0050	2.33	-.0033	100.%	0.00	0.0000	55.%	.0010	2.41	8000	224
447	29.09	0.	125.	.12	-.0050	.0040	2.35	-.0038	100.%	0.00	0.0000	55.%	.0035	2.37	7300	224
448	29.05	0.	125.	0.00	-.0015	.0050	2.35	-.0033	100.%	0.00	0.0000	55.%	.0015	2.37	7100	224
449	30.52	5180.	100.	0.00	.0035	.0085	2.33	-.0043	100.%	0.00	.0060	35.%	.0045	2.45	38200	225
450	28.73	5180.	110.	0.00	.0040	.0090	2.34	-.0043	100.%	0.00	.0040	35.%	.0005	2.43	25800	225
451	30.92	5180.	95.	0.00	.0040	.0100	2.31	-.0043	100.%	0.00	.0050	35.%	.0005	2.41	32100	225
452	28.88	5180.	125.	0.00	0.0000	0.0000	2.32	-.0113	0.%	0.00	.0050	35.%	0.0000	2.49	132700	200
453	29.61	3830.	185.	0.00	.0015	0.0000	2.38	-.0033	30.%	0.00	0.0000	45.%	.0005	2.44	48800	200
454	30.65	3830.	165.	0.00	-.0010	0.0000	2.37	-.0033	30.%	0.00	0.0000	45.%	.0005	2.38	43600	224
455	29.97	3830.	165.	.12	-.0005	0.0000	2.34	-.0038	30.%	0.00	0.0000	45.%	.0010	2.38	48900	224
456	29.55	3830.	195.	.12	-.0055	0.0000	2.38	-.0038	30.%	0.00	0.0000	45.%	.0005	2.39	48700	200
457	29.17	5354.	190.	0.00	.0010	0.0000	2.39	-.0013	40.%	0.00	.0010	45.%	0.0000	2.52	7800	224
458	30.10	5354.	195.	.23	0.0000	0.0000	2.39	-.0023	40.%	0.00	.0010	45.%	.0035	2.42	9900	224
459	30.31	5354.	190.	.12	0.0000	0.0000	2.39	-.0018	45.%	0.00	.0010	45.%	.0030	2.43	6600	224
460	28.62	5354.	195.	0.00	-.0040	0.0000	2.39	-.0013	50.%	0.00	.0010	45.%	.0050	2.53	7800	224
461	29.95	3830.	160.	.13	0.0000	0.0000	2.45	.0082	100.%	.29	.0040	55.%	0.0000	2.48	20000	224
462	30.09	3830.	160.	0.00	.0010	0.0000	2.47	.0077	100.%	.31	.0040	55.%	.0005	2.50	23800	225
463	29.73	3830.	145.	.13	-.0005	0.0000	2.48	.0072	100.%	.29	.0020	55.%	.0005	2.46	27700	224
464	28.21	3830.	195.	0.00	.0005	0.0000	2.46	.0077	100.%	.29	.0050	55.%	.0010	2.60	29900	224
465	30.06	3830.	65.	.25	-.0005	.0100	2.36	-.0053	100.%	.15	0.0000	45.%	.0005	2.42	21700	224
466	30.01	3830.	60.	.12	0.0000	.0095	2.37	-.0048	100.%	.17	0.0000	45.%	0.0000	2.47	21300	224
467	29.99	3830.	55.	.12	.0005	.0095	2.39	-.0048	100.%	.15	0.0000	45.%	0.0000	2.43	19300	224
468	29.87	3830.	35.	0.00	0.0000	.0090	2.37	-.0043	100.%	.15	0.0000	45.%	0.0000	2.43	24500	224
469	30.31	5354.	60.	.20	0.0000	0.0000	2.40	-.0008	50.%	.82	.0025	45.%	0.0000	2.38	99800	206
470	29.75	5354.	65.	.20	0.0000	0.0000	1.13	-.0018	40.%	.80	.0020	43.%	0.0000	2.36	96400	206
471	30.35	5354.	65.	.20	0.0000	0.0000	2.39	-.0018	40.%	.82	.0020	43.%	0.0000	2.32	93400	205
472	29.25	5354.	95.	0.00	0.0000	0.0000	2.39	-.0013	40.%	.79	.0020	43.%	0.0000	2.39	80500	206
473	28.84	5354.	20.	0.00	.0010	.0080	2.38	-.0033	100.%	.77	.0100	40.%	.0010	2.64	27200	224
474	29.67	5354.	60.	0.00	0.0000	.0070	2.39	-.0023	100.%	.80	.0050	40.%	0.0000	2.50	19700	224
475	28.32	5354.	30.	0.00	0.0000	.0080	2.38	-.0033	100.%	.76	.0050	35.%	0.0000	2.54	36900	224
476	30.08	5354.	55.	0.00	0.0000	.0070	2.39	-.0033	100.%	.85	.0090	35.%	0.0000	2.56	21200	224
477	30.69	2726.	140.	0.00	-.0030	.0050	2.37	-.0023	100.%	.59	.0050	40.%	0.0000	2.46	16200	224
478	29.69	2726.	135.	0.00	-.0015	.0045	2.37	-.0013	100.%	.55	.0050	40.%	.0005	2.44	11700	224
479	30.24	2726.	130.	.08	-.0020	.0032	2.37	-.0020	100.%	.57	.0050	40.%	.0005	2.43	12600	224
480	29.11	2726.	180.	0.00	0.0000	.0050	2.37	-.0023	100.%	.56	.0070	40.%	.0030	2.44	19300	224

APPENDIX D

FRACTOGRAPHY

After fatigue testing had been completed, approximately 30 specimens were selected for fractography. The fracture faces were cut out of the specimens, and these small sections were prepared for fractographic examination. All specimens were photographed at approximately 12x. Specimens were then photographed using either an AMR-1000 scanning electron microscope or an Etec Autoprobe microprobe. The microprobe automatically adds significant identification to each print; specifically, two lines of information are printed. The first line is a length bar with the length stated in microns. The second line has five elements of information: (1) a number and the powers of 10 which give the magnification of the print (for example, 05-1 would be 50x and 02-2, 200x), (2) the operating voltage in kilovolts, (3) the probe distance in millimeters, (4) the specimen sequence number, and (5) a unique negative number.

Each photograph shown below has been identified as to specimen sequence number. The type of micrograph, as well as features of each photograph, have been explained. These photographs are representative of the varieties of failures observed during the test program.

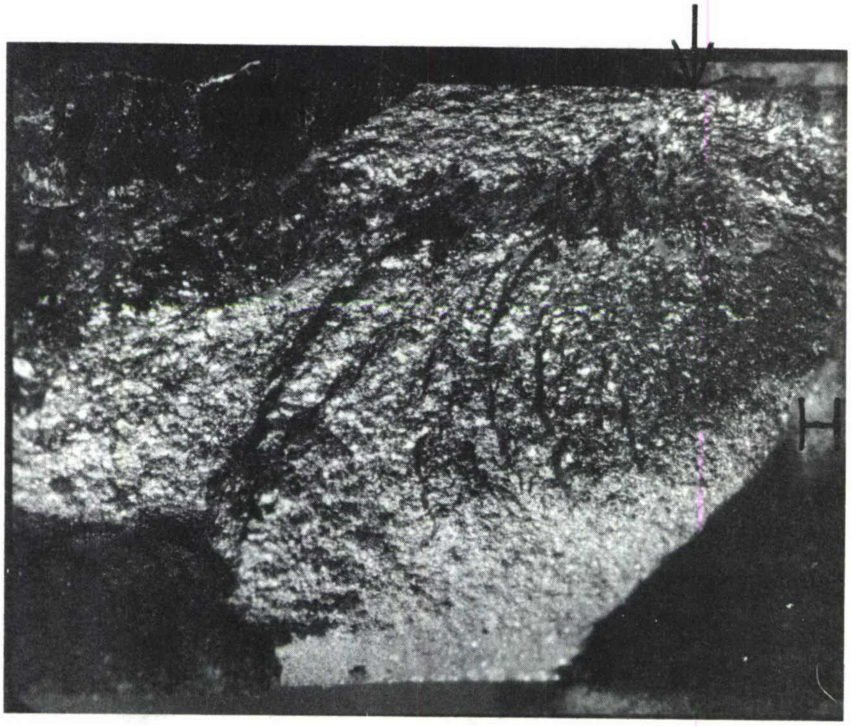

Figure 185. Specimen Sequence Number 45, Failure Code 121, Magnification 12x

The fatigue crack began under the fastener head at the →. The crack broke through to the fastener hole, H. The region M shows compressive damage as the fastener head impacted here during the shutdown cycle.

Figure 186. Microprobe View of Specimen Sequence Number 45; Magnification 100x

The fastener head F and initiation site → are visible. There are some signs of fretting debris in the crack initiation area.

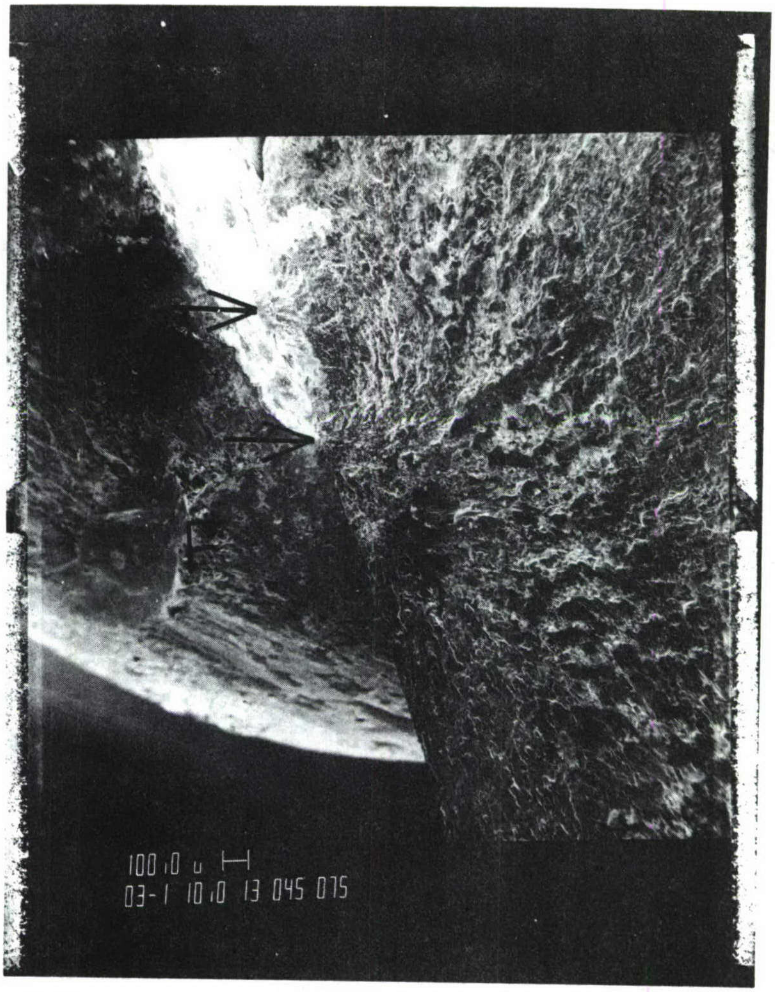

Figure 187. Microprobe View of Specimen Sequence Number 45; Magnification 30x

This shows the fastener head F and the initiation site → at the edge of the fastener head.

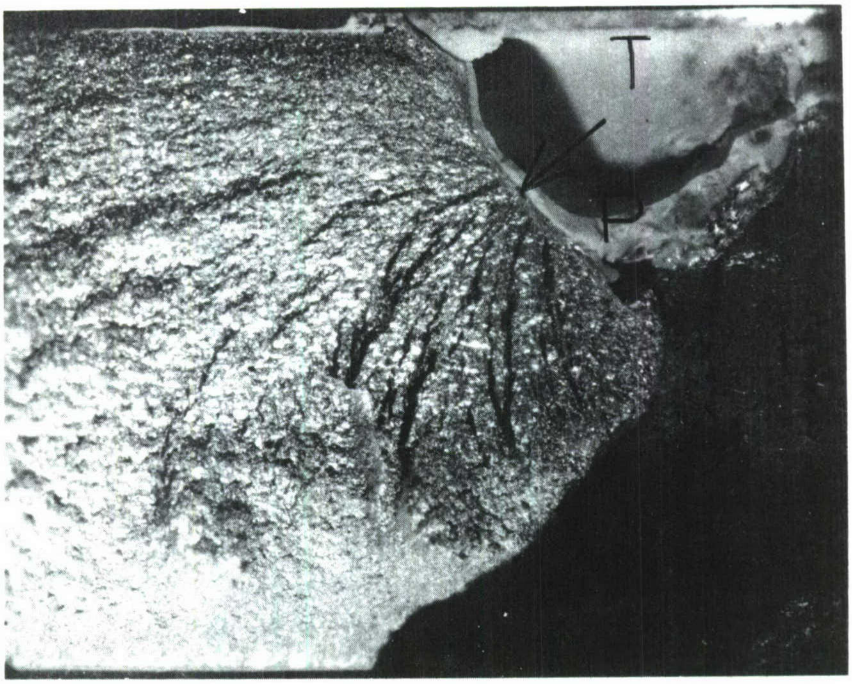

Figure 188. Specimen Sequence Number 41, Failure Code 112; Magnification 12x

This specimen failed at a tool mark, T, caused by a drill breaking. The tool mark was concealed by the fastener head. A layer of zinc chromate primer, P, can be seen in the tool mark. The fastener hole, H, is also visible.

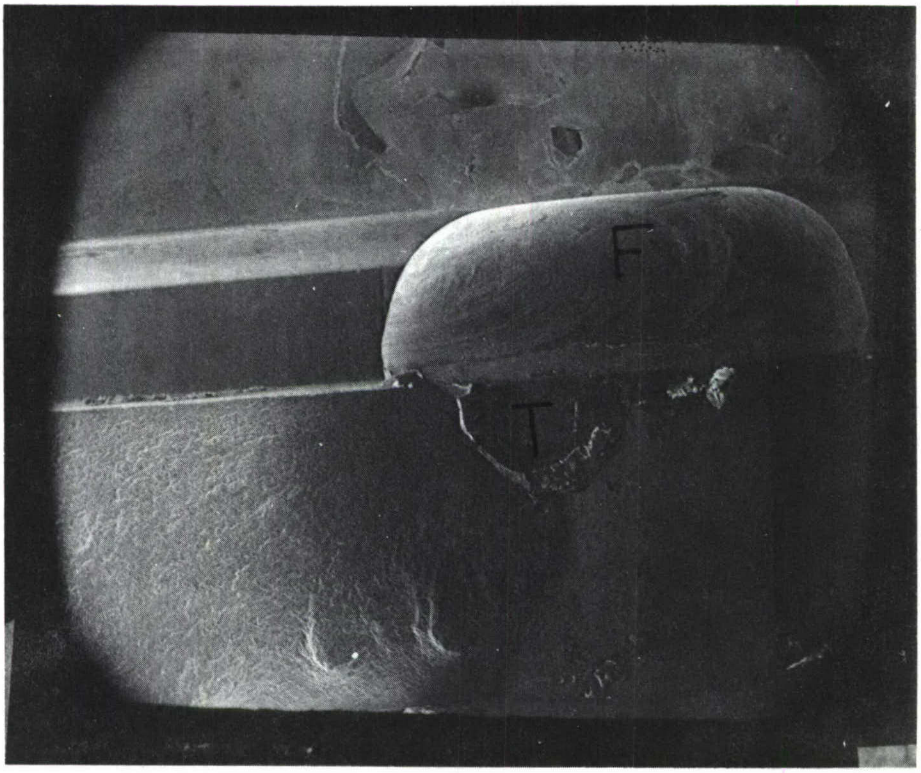

Figure 189. Scanning Electron Microscope View of Specimen Sequence Number 41; Magnification 10x

This view shows the tool mark T under the fastener head F.

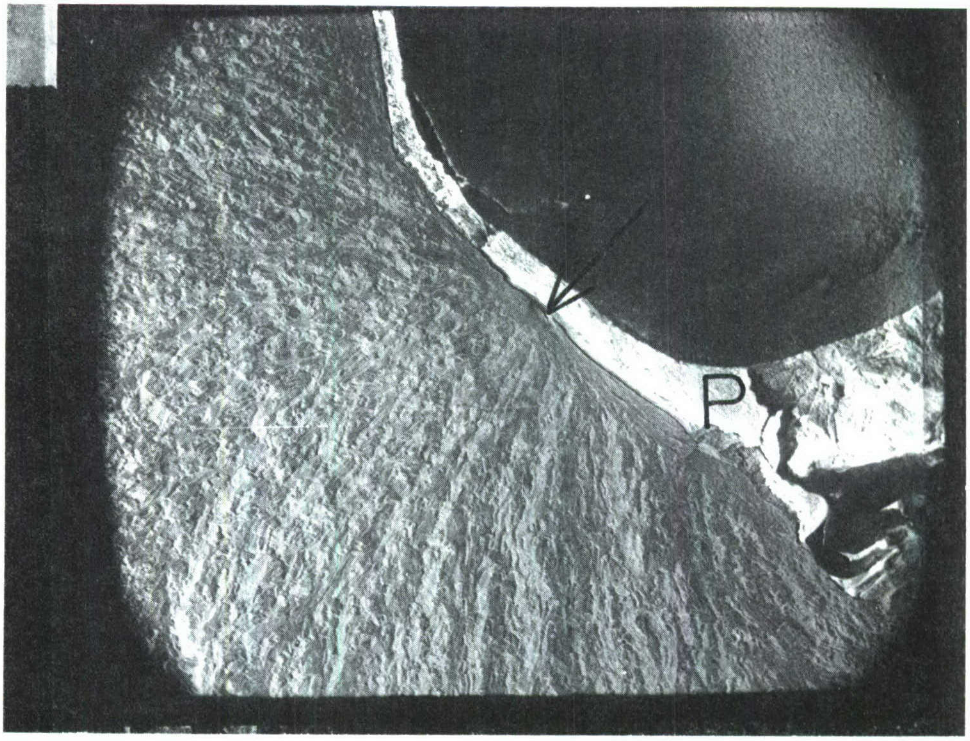

Figure 190. Scanning Electron Microscope View of Specimen Sequence Number 41; Magnification 50x

The failure initiation site is indicated by an →. This site appears to be at a burr formed by the incompleted drilling action of the broken drill bit. The zinc chromate primer, P, is charging even though it was lightly coated with graphite.

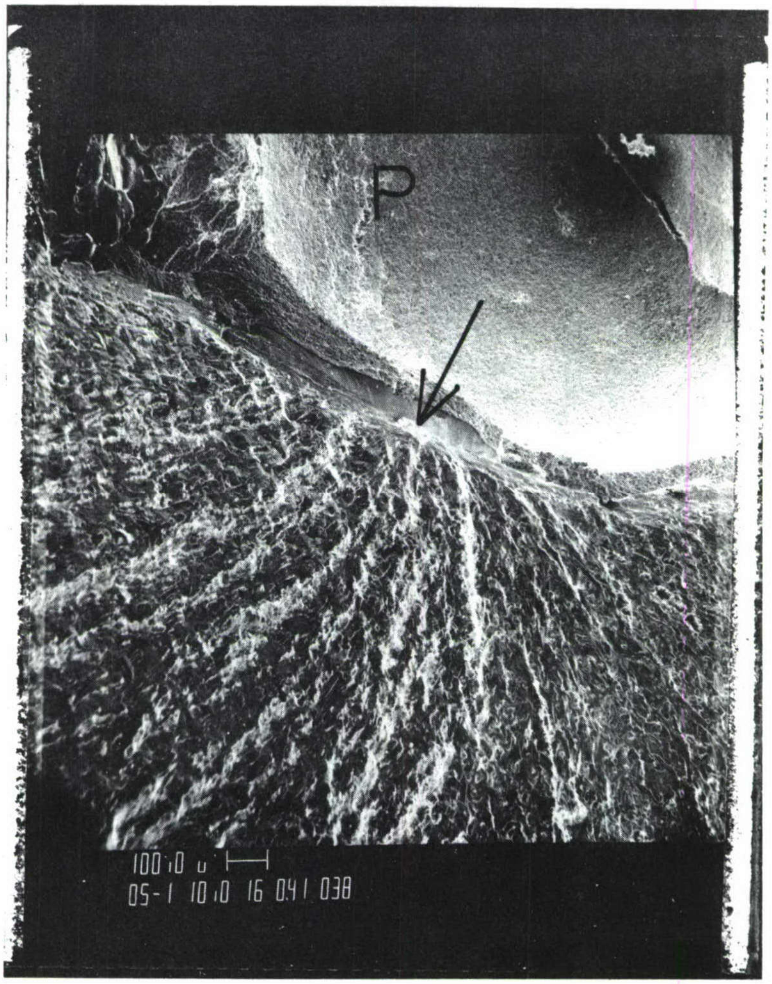

Figure 191. A Microprobe View of Specimen Sequence Number 41; Magnification 50x

The primer, P, and crack initiation site → are easily identified.

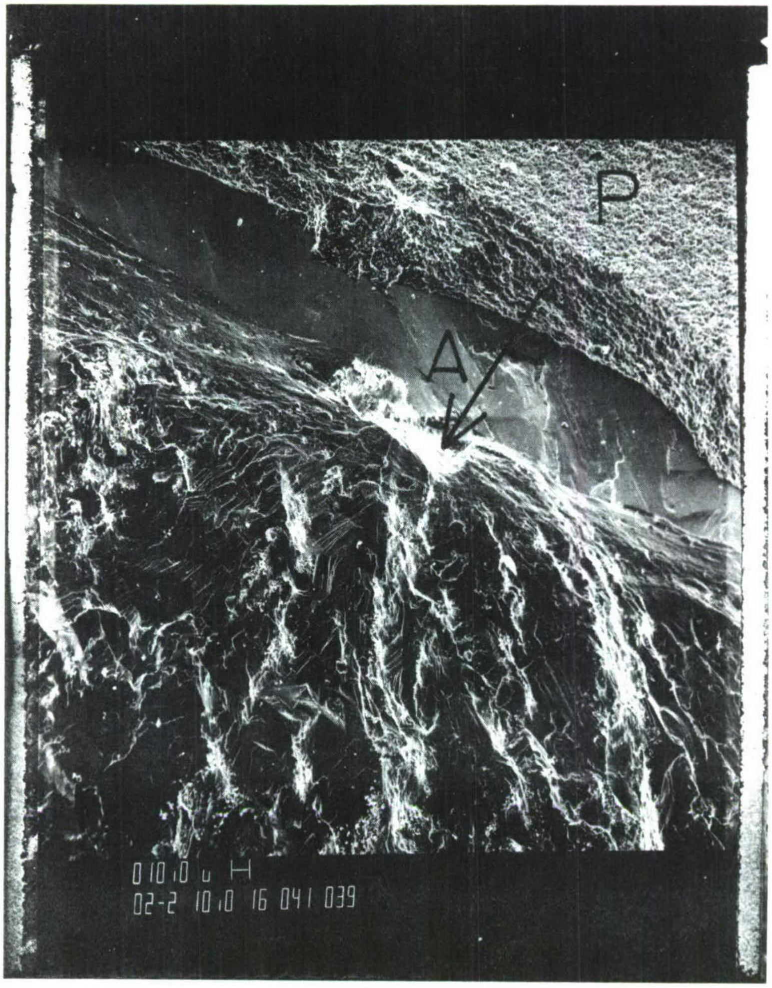

Figure 192. Electron Microprobe of Specimen Sequence Number 41; Magnification 200x

Just above the crack initiation site there appears to be a region of the aluminum, A, which was being cut by the broken bit.

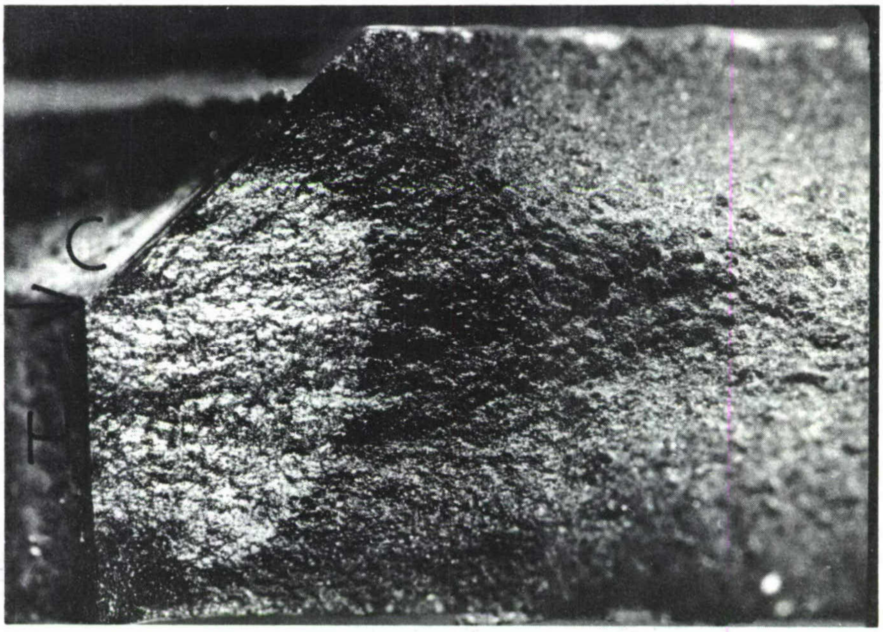

Figure 193. Specimen Sequence Number 99, Failure Code 123; Magnification 12x

The hole, H, and countersink, C, are visible. The failure origin is indicated by →.

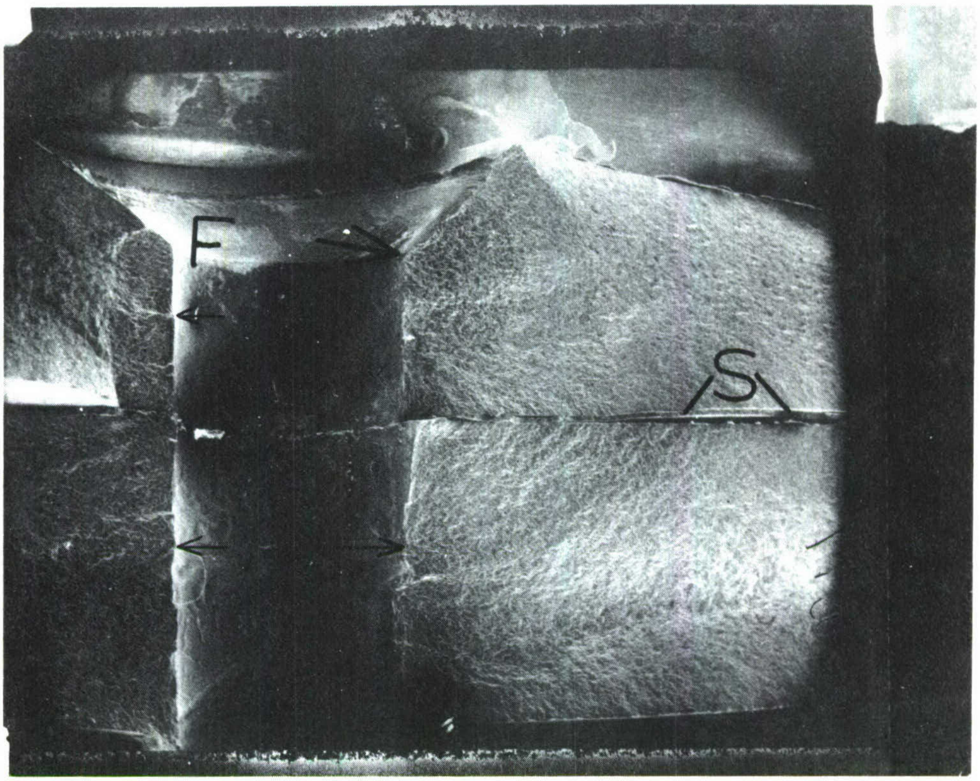

Figure 194. Scanning Electron Microscope View of Specimen Sequence Number 99; Magnification 7x

The principal crack origin is shown with the large arrow, while smaller crack origins have small arrows indicating them. The fastener head shape, F, shows the image of the fastener head in a countersink which is 4° off vertical. The faying surface sealant, S, can also be seen.

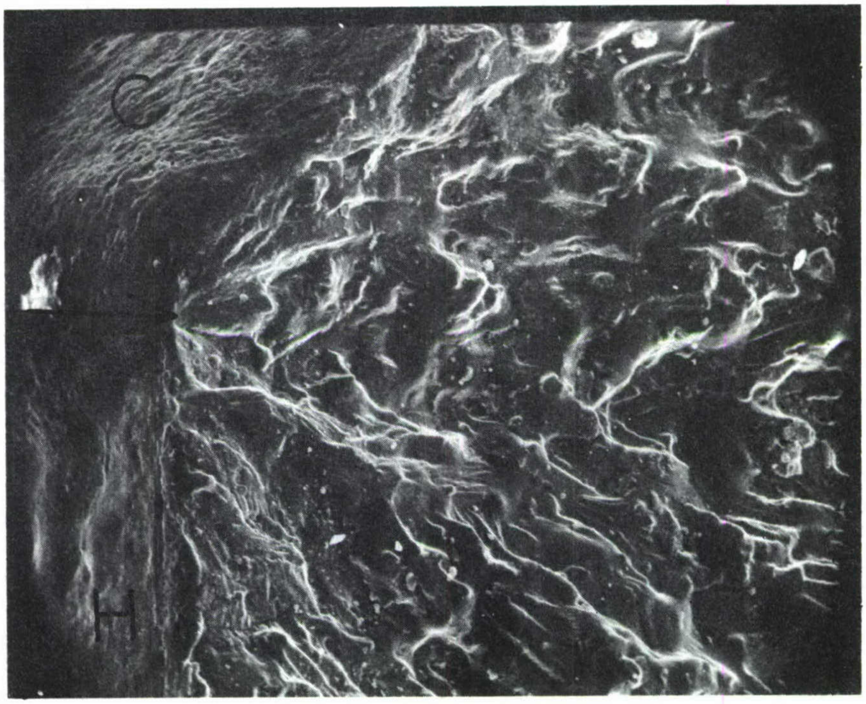

Figure 195. Scanning Electron Microscope View of Specimen Sequence Number 99; Mangification 175x

Note the difference in surface texture of the countersink, C, RHR $\sim$ 32 microinches and the hole, H, RHR $\sim$ 180 microinches. The hole was intentionally roughened. The crack origin was just below the countersink.

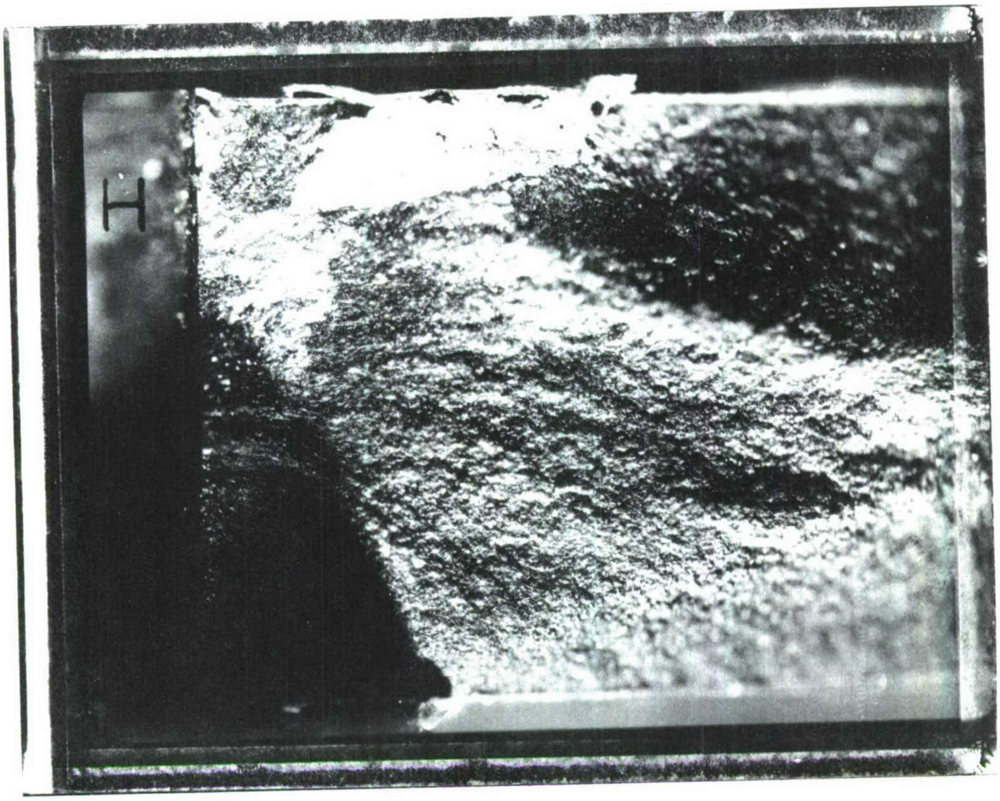

Figure 196. Specimen Sequence Number 148, Failure Code 214; Magnification 12x

A series of crack initiation sites along the hole, H, can be seen.

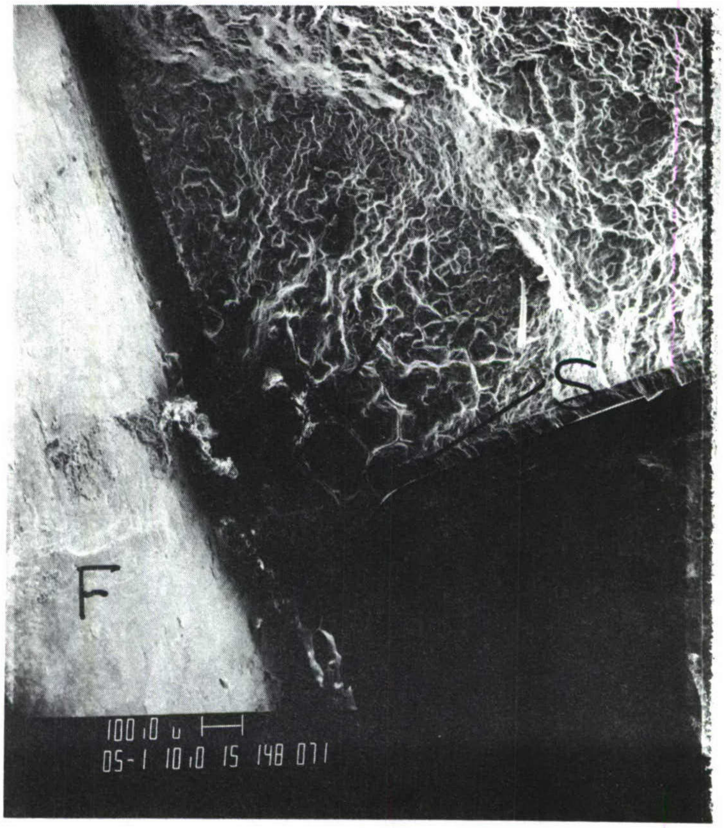

Figure 197. Microprobe View of Specimen Sequence Number 148; Magnification 50x

The fastener, F, is still in the hole, and sealant, S, can be seen in the faying surface. One crack initiation site appears to have been at the corner of the hole and the faying surface.

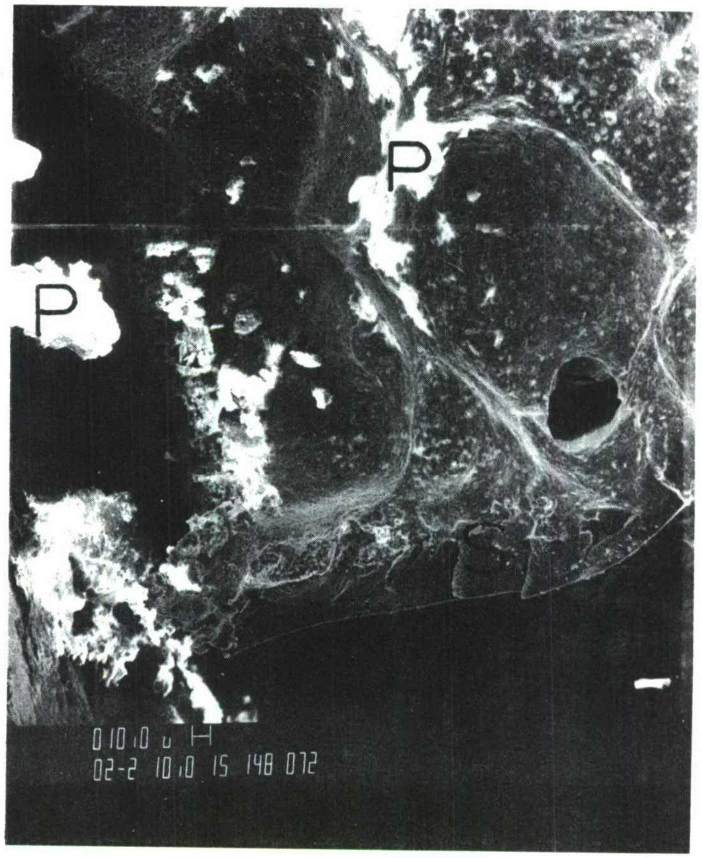

Figure 198. Scanning Electron Microscope of Specimen Number 148; Magnification 200x

Note the bubble, B, in the sealant, S, which moved over this crack initiation site. The zinc chromate primer, P, has also moved into the crack area and has charged in this view.

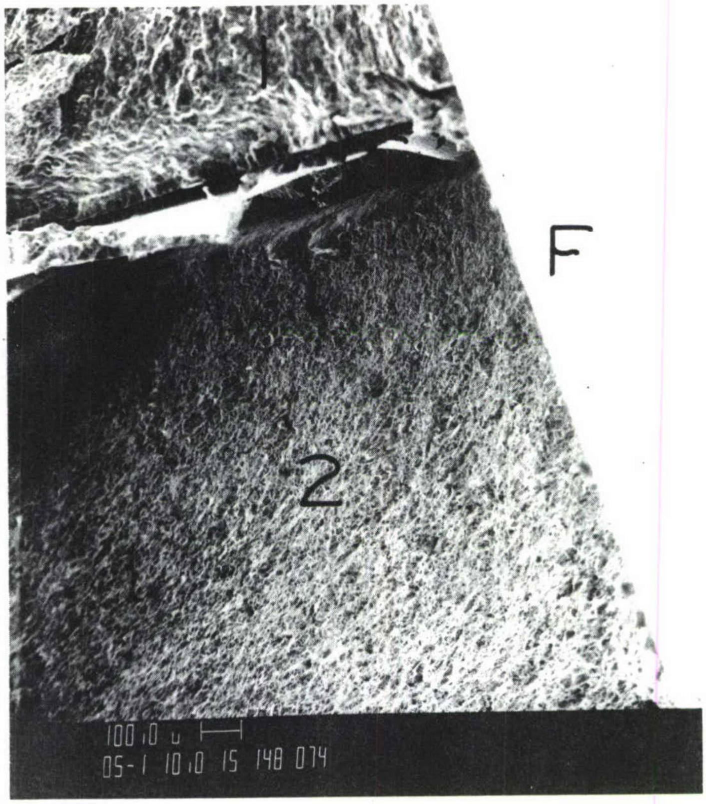

Figure 199. Microprobe View of Specimen Sequence Number 148; Magnification 50x

This shows the sealant, S, and the fastener, F. Surface 1 shows crack growth, while Surface 2 shows no crack but overload failure.

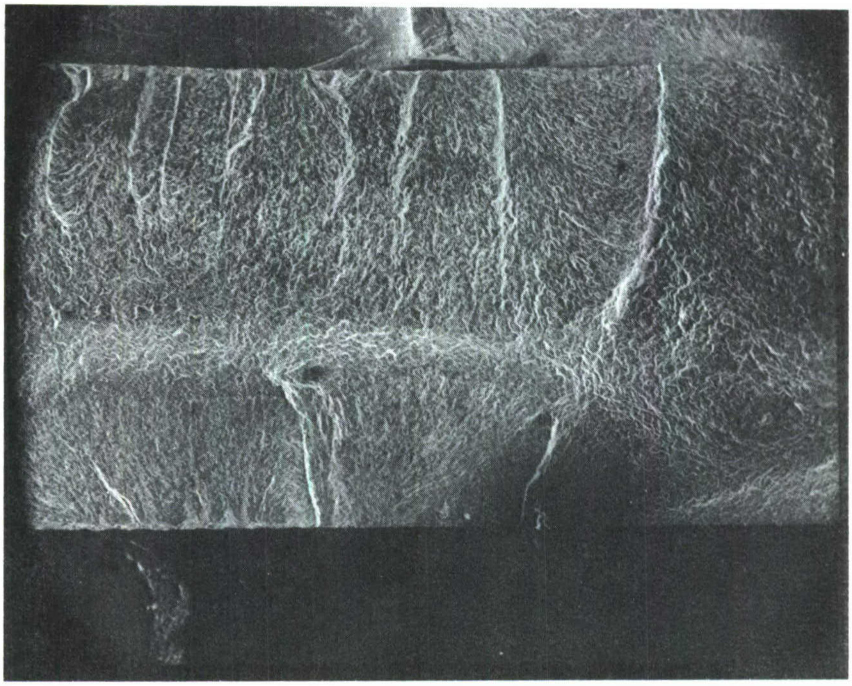

Figure 200. Specimen Sequence Number 470, Failure Code 206; Magnification 12x

This shows a series of cracks growing in from each surface and joining in the center of the sheet. High preload and a deep countersink forced more frictional load transfer, and failure occurred about 0.1" away from the hole.

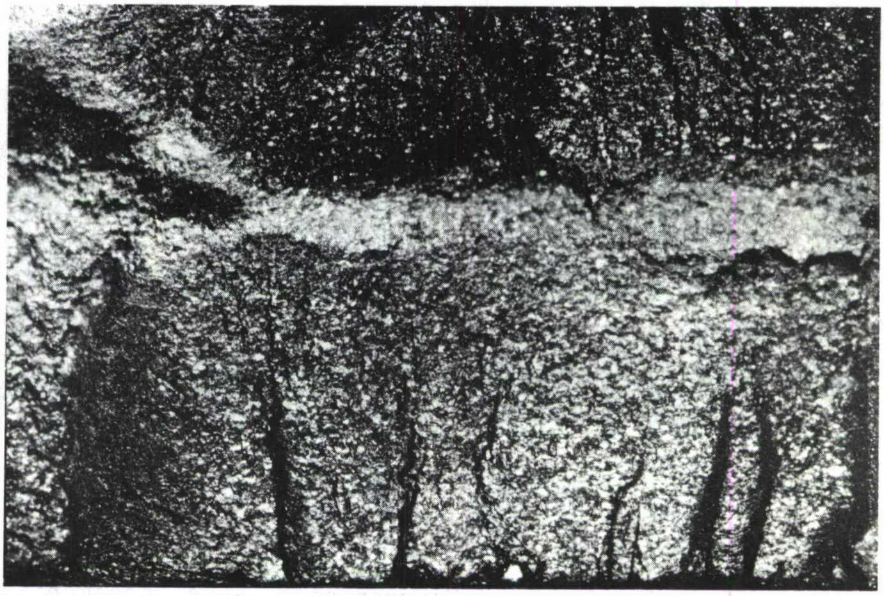

Figure 201. Scanning Electron Microscope View of Specimen Sequence Number 470; Magnification 10x

This shows the multiple initiation sites on both faying surfaces.

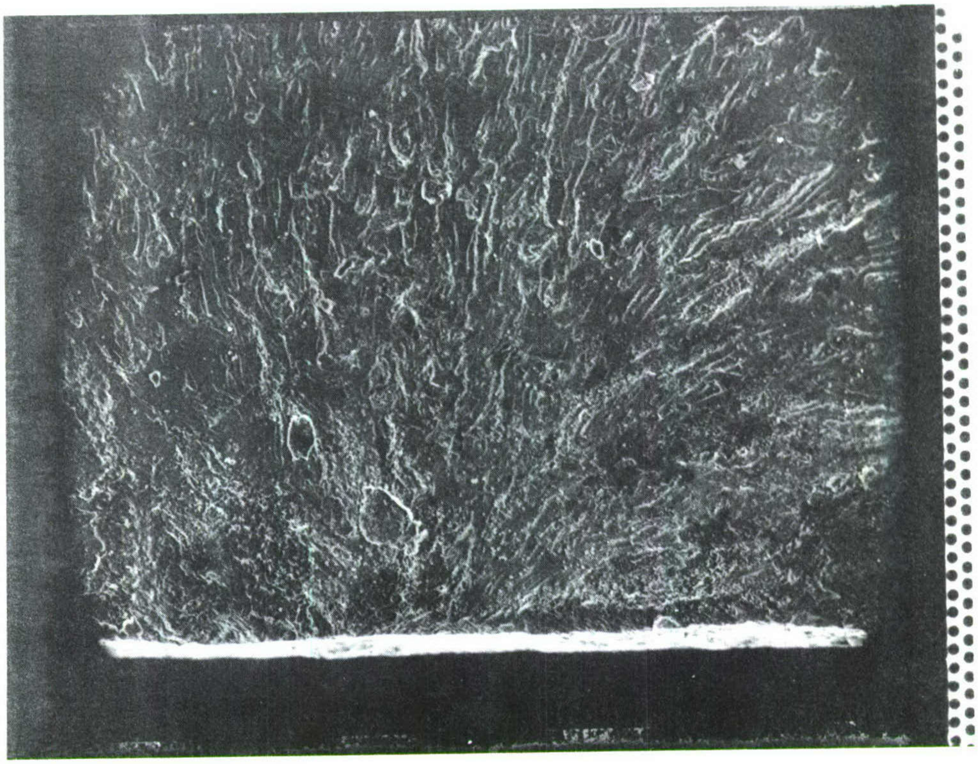

Figure 202. Scanning Electron Microscope View of Specimen Sequence Number 470; Magnification 100x

This shows a typical crack initiation region on the specimen edge.

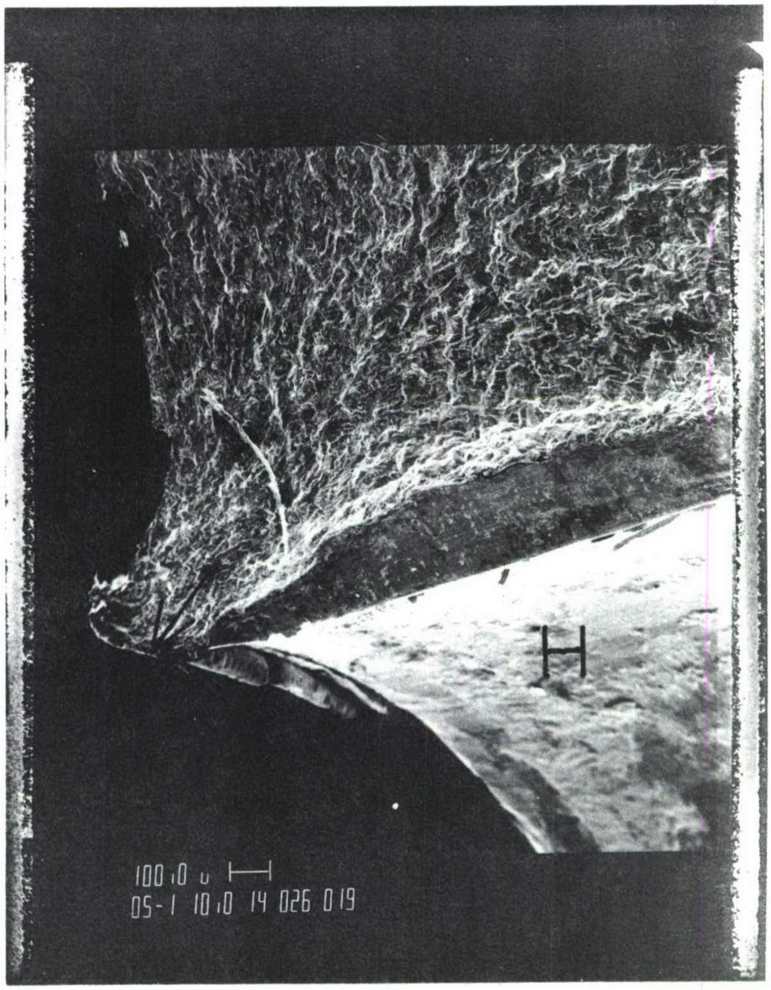

Figure 203. Microprobe View of Specimen Sequence Number 26; Magnification 50x

Failure Code 117. This specimen was not deburred, and the failure initiated (→) at the burr on the exit side of the hole, H. No collar was installed on the fastener.

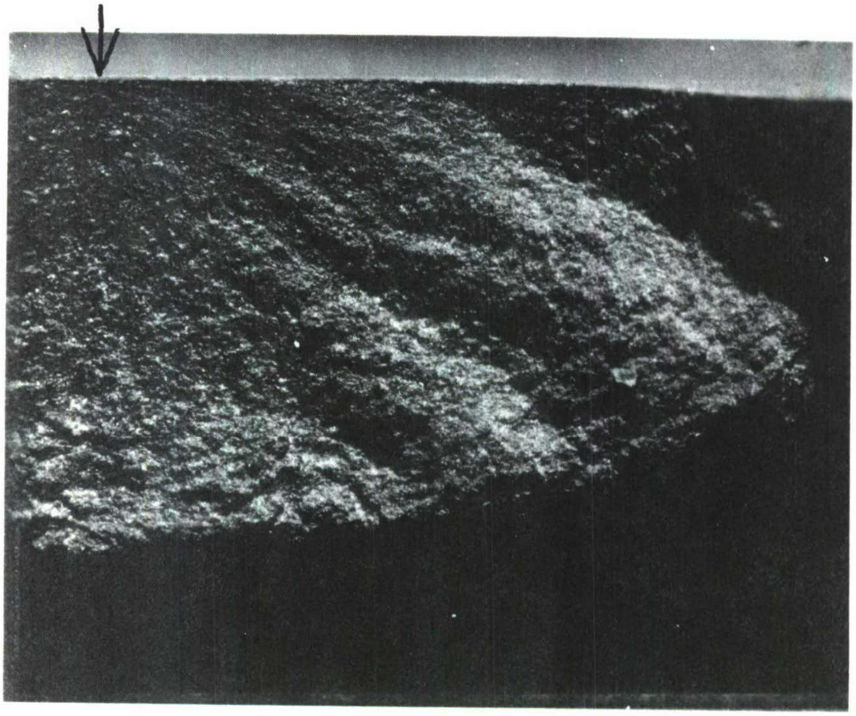

Figure 204. Specimen Sequence Number 42, Failure Code 100; Magnification 12x

The failure origin → is on the side of the specimen in the reduced section but not at a hole. The crack is illuminated, but the portion of the specimen showing overload is in the shadow.

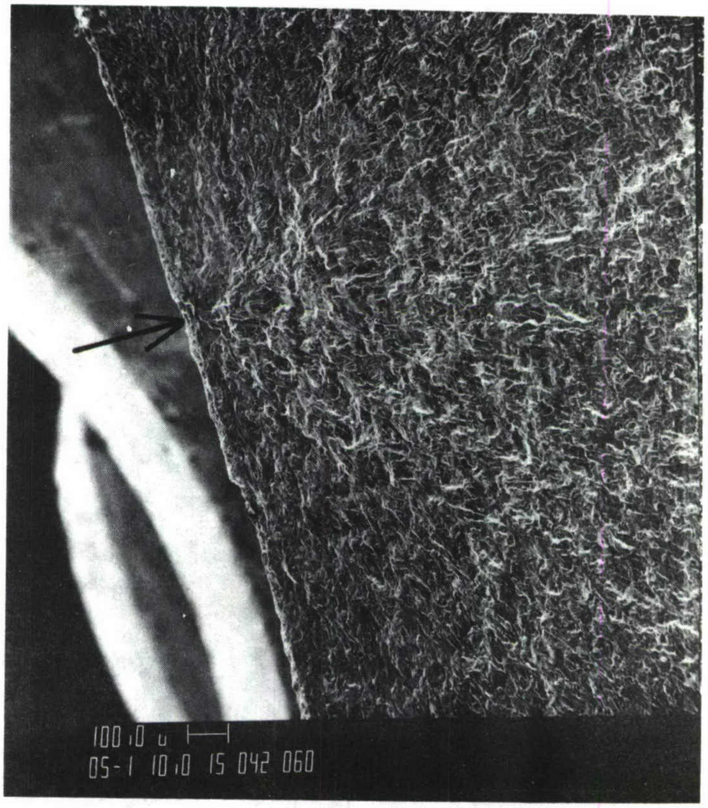

Figure 205. Microprobe View of Specimen Sequence Number 42; Magnification 50x

The initiation site → is more clearly seen and the corrosion pit is visible also.

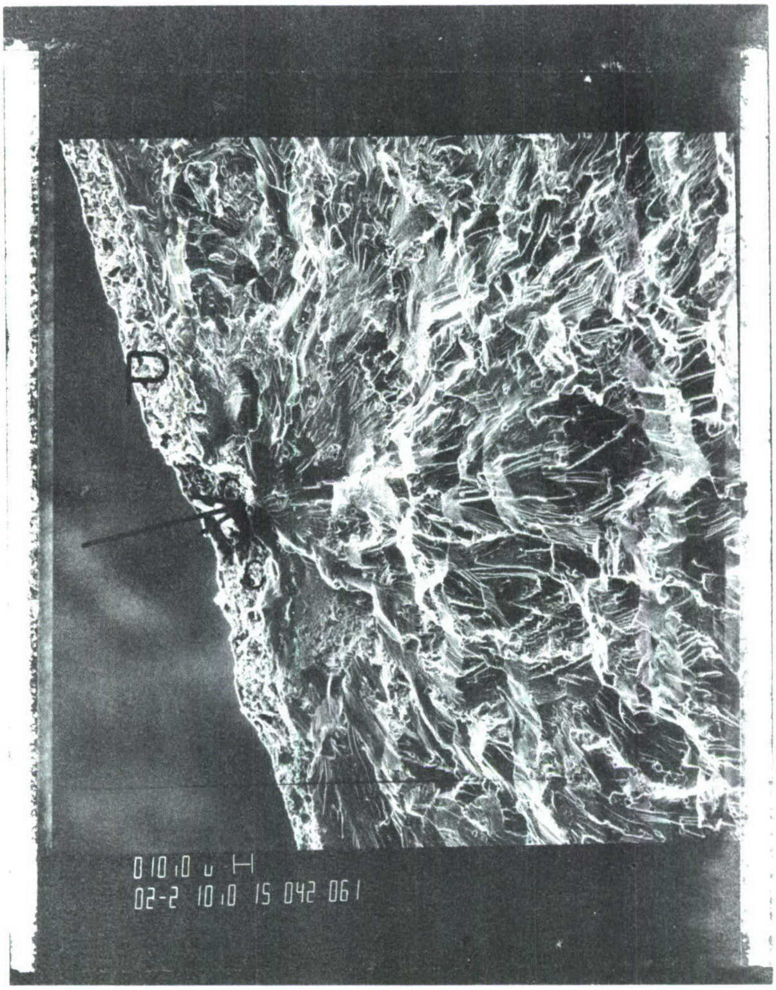

Figure 206. Microprobe View of Specimen Sequence Number 42; Magnification 200x

The corrosion pit, C, is easily seen although the primer, P, has filled it making the specimen surface smooth.

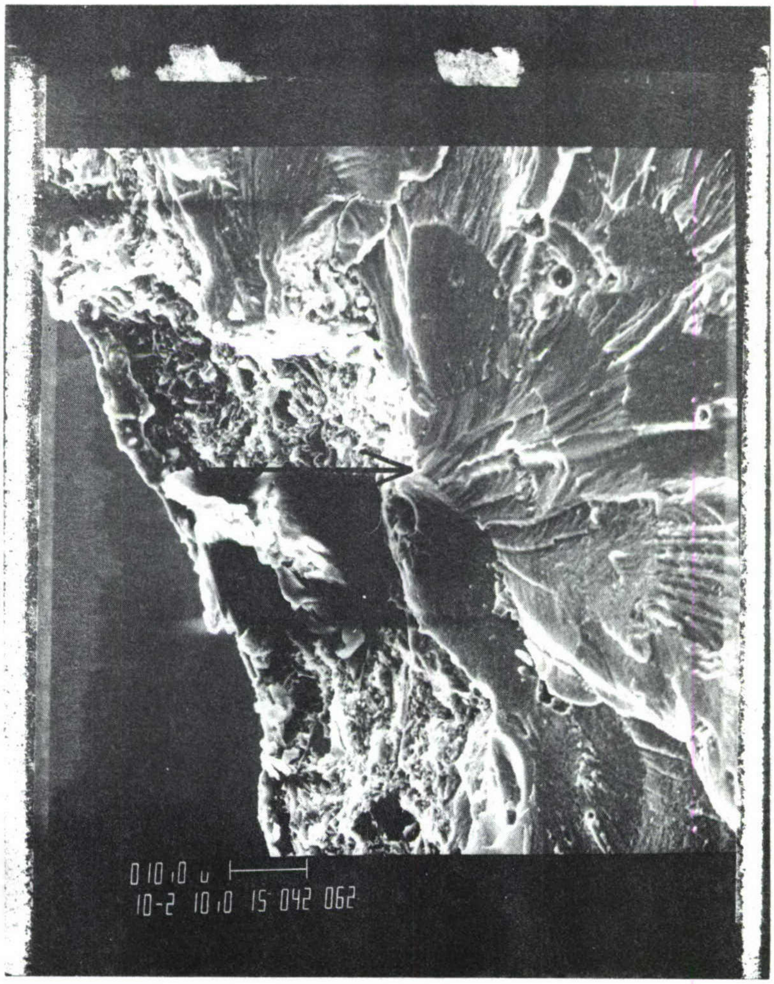

Figure 207. Microprobe View of Specimen Sequence Number 42; Magnification 1000x

The initiation site → is visible in the pit. Grain boundaries can also be seen. Charging of the nonconductive epoxy creates the bright spot in the pit.

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